GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

MAERSK LINE

A.P. MØLLER-MÆRSK A/S

FINAL REPORT IN THE FRAMEWORK OF THE ADVANCED TECHNOLOGY PLATFORM:

“BIOMASS FOR THE 21ST CENTURY: INTEGRATED BIOREFINING TECHNOLOGIES FOR SHIPPING FUELS AND BIOBASED CHEMICALS (B21ST)”

CONTRIBUTION TO “WORKPAKAGE 8 – MARKET OUTLOOK”

18. SEPTEMBER 2012

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# CONTENT

<table>
<thead>
<tr>
<th>1 Executive summary</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Supply markets – woody biomass</td>
<td>18</td>
</tr>
<tr>
<td>3 Supply markets – agricultural biomass</td>
<td>30</td>
</tr>
<tr>
<td>4 Results – biomass potentials</td>
<td>41</td>
</tr>
<tr>
<td>5 Sustainability and certification</td>
<td>56</td>
</tr>
<tr>
<td>6 Sustainability ranking</td>
<td>65</td>
</tr>
<tr>
<td>7 Regional ranking</td>
<td>76</td>
</tr>
<tr>
<td>8 Annex</td>
<td>80</td>
</tr>
<tr>
<td>9 Contact information</td>
<td>86</td>
</tr>
</tbody>
</table>
## GLOSSARY I

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AAC</td>
<td>Annual allowable cut</td>
</tr>
<tr>
<td>BMVBS</td>
<td>Bundesministerium für Verkehr, Bau und Stadtentwicklung</td>
</tr>
<tr>
<td>CDM</td>
<td>Clean development mechanism</td>
</tr>
<tr>
<td>CPO</td>
<td>Crude palm oil</td>
</tr>
<tr>
<td>EFB</td>
<td>Empty fruit bunch</td>
</tr>
<tr>
<td>EU</td>
<td>European Nation</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FFB</td>
<td>Fresh fruit bunch</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross domestic product</td>
</tr>
<tr>
<td>GTAP</td>
<td>Global Trade Analysis Project</td>
</tr>
<tr>
<td>HW</td>
<td>Hard wood</td>
</tr>
<tr>
<td>MAI</td>
<td>Mean annual increment</td>
</tr>
<tr>
<td>MDF</td>
<td>Mean density fiberboard</td>
</tr>
<tr>
<td>OSB</td>
<td>Oriented strand board</td>
</tr>
<tr>
<td>PK</td>
<td>Palm kernel</td>
</tr>
<tr>
<td>PKS</td>
<td>Palm kernel shells</td>
</tr>
<tr>
<td>POME</td>
<td>Palm oil mill effluent</td>
</tr>
<tr>
<td>SW</td>
<td>Soft wood</td>
</tr>
<tr>
<td>UNECE</td>
<td>United Nations Economic Commission for Europe</td>
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### Certification Systems

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<td>BSI</td>
<td>Better Sugarcane Initiative</td>
</tr>
<tr>
<td>FSC</td>
<td>Forest Stewardship Council</td>
</tr>
<tr>
<td>ISCC</td>
<td>International Sustainability &amp; Carbon Certification</td>
</tr>
<tr>
<td>PEFC</td>
<td>Program for Endorsement of Forest Certification Schemes</td>
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<tr>
<td>RSB</td>
<td>Roundtable on Sustainable Biofuels</td>
</tr>
<tr>
<td>RSPO</td>
<td>Roundtable on Sustainable Palm Oil</td>
</tr>
<tr>
<td>SAN</td>
<td>Sustainable Agriculture Network</td>
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<tr>
<td>SFI</td>
<td>Sustainable Forestry Initiative</td>
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### Units

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<th>Description</th>
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<td>m³</td>
<td>Cubic meter</td>
</tr>
<tr>
<td>ha</td>
<td>Hectares</td>
</tr>
<tr>
<td>a</td>
<td>Year</td>
</tr>
<tr>
<td>m³sub</td>
<td>Cubic meter solid under bark</td>
</tr>
<tr>
<td>m³sob</td>
<td>Cubic meter solid over bark</td>
</tr>
<tr>
<td>PJ</td>
<td>Peta joule</td>
</tr>
<tr>
<td>odt</td>
<td>Oven dried tons</td>
</tr>
<tr>
<td>Mtoe</td>
<td>Million tons of oil equivalent</td>
</tr>
<tr>
<td>DM</td>
<td>Dry Matter = oven dried</td>
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GLOSSARY II

The values in the table below can be used as general conversion factors between wood volume, weight and energy units. In the study, tree-specific values were used.

General conversion factors for woody biomass

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<thead>
<tr>
<th>From</th>
<th>to</th>
<th>Mm³</th>
<th>Modt</th>
<th>PJ</th>
<th>Mtoe</th>
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<td>Mm³</td>
<td></td>
<td>1</td>
<td>0,5</td>
<td>8,72</td>
<td>0,21</td>
</tr>
<tr>
<td>Modt</td>
<td></td>
<td>2</td>
<td>1</td>
<td>18,18</td>
<td>0,44</td>
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<tr>
<td>PJ</td>
<td></td>
<td>0,11</td>
<td>0,055</td>
<td>1</td>
<td>0,024</td>
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<tr>
<td>Mtoe</td>
<td></td>
<td>4,76</td>
<td>2,26</td>
<td>41,87</td>
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# Glossary III

Typical composition of different biomass assortments.

<table>
<thead>
<tr>
<th>Product</th>
<th>Cellulose %</th>
<th>Hemicellulose %</th>
<th>Lignin %</th>
<th>other contents*</th>
<th>Ca [g/KgDM]</th>
<th>P [g/KgDM]</th>
<th>Mg [g/KgDM]</th>
<th>K [g/KgDM]</th>
<th>Cl [g/KgDM]</th>
<th>S [g/KgDM]</th>
<th>Si [g/KgDM]</th>
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<tr>
<td>BARLEY</td>
<td>42-54</td>
<td>22 - 39</td>
<td>5-16</td>
<td>~4-18%</td>
<td>2,9 - 4,9</td>
<td>0,8 - 2,1</td>
<td>0,7 - 1</td>
<td>8,6 - 14</td>
<td>3,7 - 7,7</td>
<td>0,89 - 1,4</td>
<td>2,9-6,4</td>
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<tr>
<td>MAIZE STALK/STRAW</td>
<td>36,5 - 38</td>
<td>26 - 28,1</td>
<td>10,4 - 19</td>
<td>~4-18%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,5</td>
<td>1,17</td>
<td>-</td>
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<tr>
<td>MAIZE STOVER</td>
<td>37,4</td>
<td>27,6</td>
<td>18</td>
<td>~4-18%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,66</td>
<td>0,08 - 1,1</td>
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<tr>
<td>OATS</td>
<td>56</td>
<td>22</td>
<td>15</td>
<td>~4-18%</td>
<td>3,9</td>
<td>0,9</td>
<td>1,5</td>
<td>21,9</td>
<td>8,1 - 15</td>
<td>1,1 - 2,5</td>
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<tr>
<td>OIL PALM FROND</td>
<td>-</td>
<td>-</td>
<td>16,4</td>
<td>-</td>
<td>1,7</td>
<td>0,8</td>
<td>1,2</td>
<td>16,3</td>
<td>-</td>
<td>0,9</td>
<td>-</td>
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<tr>
<td>OIL PALM TRUNK</td>
<td>-</td>
<td>-</td>
<td>18,8</td>
<td>-</td>
<td>1,5</td>
<td>0,5</td>
<td>1,3</td>
<td>14,6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RICE STRAW</td>
<td>38 - 42</td>
<td>25,3 - 33</td>
<td>9 - 23,3</td>
<td>~4-20%</td>
<td>1,6 - 2,4</td>
<td>0,9</td>
<td>1,2 - 1,4</td>
<td>10,7</td>
<td>2</td>
<td>1,3</td>
<td>57-130</td>
</tr>
<tr>
<td>RICE HUSKS AND SHELLS</td>
<td>31,1</td>
<td>24,3</td>
<td>14,3</td>
<td>~4-18%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,8</td>
<td>-</td>
<td>-</td>
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<tr>
<td>RYE</td>
<td>31</td>
<td>25</td>
<td>5 - 19</td>
<td>~4-18%</td>
<td>2,8 - 3,6</td>
<td>1 - 1,5</td>
<td>0,6 - 0,9</td>
<td>9,8 - 16,8</td>
<td>1,9 - 4</td>
<td>0,6 - 1,2</td>
<td>34</td>
</tr>
<tr>
<td>SORGHUM</td>
<td>33 - 41</td>
<td>18 - 42</td>
<td>8,4 - 15</td>
<td>~4-18%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SUGAR CANE BAGASSE</td>
<td>40 - 55</td>
<td>20 - 30</td>
<td>18 - 24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,3</td>
<td>0,4</td>
<td>-</td>
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<tr>
<td>TRITICALE</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,1</td>
<td>0,8</td>
<td>0,5</td>
<td>10,5</td>
<td>0,7 - 2,7</td>
<td>0,6 - 1,1</td>
<td>-</td>
</tr>
<tr>
<td>WHEAT</td>
<td>37 - 53</td>
<td>29 - 45</td>
<td>6 - 19</td>
<td>~4-18%</td>
<td>2,1 - 3,2</td>
<td>0,8 - 1</td>
<td>0,9 - 1,1</td>
<td>7,6 - 11,8</td>
<td>1,9 - 6,1</td>
<td>0,8 - 1,6</td>
<td>23-32</td>
</tr>
<tr>
<td>SPRUCE</td>
<td>40 - 43</td>
<td>27 - 31</td>
<td>29</td>
<td>~1-3%</td>
<td>7</td>
<td>0,3</td>
<td>0,8</td>
<td>1,3</td>
<td>0,5</td>
<td>0,15</td>
<td>-</td>
</tr>
<tr>
<td>BEECH</td>
<td>46</td>
<td>35</td>
<td>18</td>
<td>~1-3%</td>
<td>2,9</td>
<td>0,4</td>
<td>0,4</td>
<td>1,5</td>
<td>0,6</td>
<td>0,15</td>
<td>-</td>
</tr>
<tr>
<td>POPLAR</td>
<td>50</td>
<td>31</td>
<td>18</td>
<td>~1-3%</td>
<td>5,1</td>
<td>1</td>
<td>0,5</td>
<td>3,5</td>
<td>0,04</td>
<td>0,31</td>
<td>-</td>
</tr>
<tr>
<td>PINUS RADIATA</td>
<td>31 - 50,6</td>
<td>21,4 - 26</td>
<td>24,8 - 39</td>
<td>~1-3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EUCALYPTUS</td>
<td>45</td>
<td>15 - 19</td>
<td>25 - 31</td>
<td>~1-3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>0,1</td>
<td>-</td>
</tr>
<tr>
<td>TEAK</td>
<td>34 - 43</td>
<td>17</td>
<td>30 - 39</td>
<td>~1-3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,99</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Other contents typically include proteins, ash, lipids and residues of storage polysaccharids such as glucans, fructans and mannans.
### GLOSSARY IV

Six regions were defined for the aggregation of results.

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<tr>
<th>Africa</th>
<th>Africa cont’d</th>
<th>North America</th>
<th>South America</th>
<th>Pacific &amp; Oceania</th>
<th>Europe</th>
<th>Asia</th>
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B21ST – WP8 – Global biofuel potentials for marine engines


7
EXECUTIVE SUMMARY – SCOPE OF WORK

Scope and key questions for WP8

Availability and cost of biomass:
- To what extent is relevant biomass feedstock available and accessible in the short-medium term, and at which cost can it be made available for commercial, large-scale application?

Sustainability of biomass
- What is the sustainability of biomass production and the end-products using a life cycle approach, and considering the potential effect of scaling up production of the biomass?

Barriers to scale
- What are the barriers to scaling up the biomass production and production of the final products? How could the barriers potentially be overcome? Barriers could be physical, political, regulatory, market-related, etc.

Work methodology
- Desktop analysis and utilization of Pöyry’s databases and models
- Assessment of existing studies, statistics and expert interviews
- Pöyry workshops including B21st consortium

Scope agreed in the framework of this study

- Assessment of technical biomass potentials (grouped by solid/liquid softwood/hardwood residues; agricultural residues by species for each region)
- Qualitative description of supplier markets including the current typical utilisation by assortment
- Preliminary Identification of most attractive supply regions for MAERSK by assortment/region

- Assessment of sustainability criteria of EU and most relevant certification schemes
- Effects of sustainability issues on up-scaling of biomass production

Qualitative assessment of
- Environmental issues
- Social issues
- Main political or regulatory barriers for biomass production
- Market-related insufficiencies
- Impacts on land use

Key findings of this study are based on the results of the workshops including the participants of the B21st consortium.
EXECUTIVE SUMMARY – FEEDSTOCKS IN SCOPE OF WORK

The following biomass raw materials and regions have been agreed during the Kick off meeting.

Feedstock

- Forest based biomass including:
  - Chipped roundwood (softwood/hardwood from forests and/or plantations)
  - Forest harvesting residues (softwood/hardwood from forests and/or plantations)
  - Sawmill residues (softwood/hardwood)
  - Pulpmill residues (softwood pulp/hardwood pulp)

- Agricultural by-products including:
  - Cereal residues (straw and husks from wheat, barley, corn, rice, etc.)
  - Sugar cane bagasse
  - Palm oil residues (empty fruit bunches, kernel shells and prunings)

Regions under investigation

- Africa
- Asia
- Pacific and Oceania
- Europe / Eastern Europe (Non EU) and Russia
- North America
- South America

Time frame

- Short term (until 2015) and medium term (2020)
EXECUTIVE SUMMARY – APPROACH

A stepwise approach was used to assess the biomass potentials and give recommendations.

- **Biomass potentials and markets**
  - In a first step biomass potentials for the different feedstocks were calculated taking into account publicly available data and statistics, as well as data from the Pöyry database.
  - The different biomass assortments and uses competing with energetic utilization were described. An outlook on the qualitative drivers of the markets was given.

- **Sustainability**
  - A screening of relevant certification schemes and sustainability criteria in use was carried out.
  - Based on economic, ecologic and social criteria a description of the status quo was derived on a country basis and then aggregated to regional results.

- **Recommendations**
  - The data and results compiled are consolidated in a regional benchmark taking into account the priorities of MAERSK and the consortium partners.
EXECUTIVE SUMMARY – GLOBAL BIOMASS POTENTIALS

Biomass potentials in forestry and agriculture will increase until 2020. Displayed is the technical biomass supply potential* from 2010 to 2020. Especially the agricultural potential (harvesting and processing residues) is growing significantly.

* Methodology for the calculation of the potentials is shown in detail in chapter “Methodology”.

Million odt

<table>
<thead>
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<th>Agriculture</th>
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</tr>
<tr>
<td>2020</td>
<td>2500</td>
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</tr>
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</table>

Forestry
Agriculture
EXECUTIVE SUMMARY – GLOBAL MEGATRENDS

Key global megatrends impacting global biomass potentials differ in the forestry and the agricultural sector. Both result in an increased availability of biomass suitable for the production of marine biofuels.

- Both the forest and agricultural products see increasing prices of raw materials in the last few years after a long historic decline of prices during the last decades. The main reason is increasing demand in both sectors primarily based on growing world population and recovery of the industry after world economic crisis. In the forest sector industry is struggling to pass price increases in production costs to end consumers. Subsidized bioenergy as competitor is putting additional pressure on the sector.

- In the forest sector price increase and growing supply is additionally based on growing demand from the bioenergy sector on top of the industrial demand. Despite the global forest area is still decreasing, management of existing forests is improving and highly productive plantations increase their share in global wood supply primarily in the southern hemisphere which leads globally to growing supply.

- In the agricultural sector price increase and growing supply is based on growing world population and changing food habits. Additionally markets are getting more volatile due to higher frequency of climatic extremes. The growing prices and increased volatility are claimed by many NGO’s on the background of securing food supply especially in developing countries. On the other hand this historic turnaround in food prices will attract more investments in agriculture and thus increase production of food and the availability of agro-residues substantially. This is also a historic chance to re-cultivate agricultural land in many developing countries after a long period of de-investment and desertification. This could strengthen the income and improve living conditions in rural areas of many developing countries.
EXECUTIVE SUMMARY – FORESTRY

The following woody biomass baskets look most promising for the production of marine biofuels in industrial scale.

Primary biomass products by region

- **South America** shows strong increase of forest based biomass potentials and corresponding growth of demand.
- Forest based biomass potentials decrease in **North America and Russia**, but still are promising due to existing huge surplus.
- Despite growing competition for roundwood, **Europe is promising due to** advanced forest biomass handling and sustainable forest management in place.

Residues:

- **Pulpmill residue** potential is growing largest in **China and South America**. **North America and Europe** have a traditionally strong position in pulp production.
- **Sawmilling residues** are most attractive in regions with high supply volumes and low development of the pellet industry, these are **Latin America** (incl. mature fast growing plantations). Traditionally **North America** and **Europa** have a strong position in the sawmilling sector.

- **Fuelwood** is the dominant assortment in major regions of the world, which should not be in the focus of wood sourcing considerations (especially **Africa and Asia**).
EXECUTIVE SUMMARY – AGRICULTURE

The following agricultural residue assortments look most promising for the production of marine biofuels in industrial scale.

Assortments and future top regions:

- **Maize residues** are the dominating agricultural by-product globally (approx. 1400 million odt). Production is largest in **North America** (approx. 450 million odt) and **China** (approx. 210 million odt).

- **Wheat residue** production is largest in **Asia incl. China** (approx. 380 million odt), **North America & Europe** (each approx. 130 million odt) and **Russia** (approx. 90 million odt).

- **Rice** production is largest in **Asia** (approx. 540 Million odt), **China** (approx 210 million odt) and **Latin America** (approx. 30 million odt).

- **Sugar cane residues** count for approx. 380 million odt globally with a focus in **Latin America (and Asia)**.

- **Palm oil residues** count for approx. 230 million odt globally with a clear focus in **Asia**.

- Currently maize and wheat straw are mainly used for animal feed while rice straw burning is common practice due to phytosanitary concerns. Rice husks are used as animal bedding or feed. Sugar cane bagasse is primarily used as biofuel, fibre or animal feed. Palm oil residues are primarily used as biofuel, fertilizer or fibre.
EXECUTIVE SUMMARY – RECOMMENDATIONS

Based on the current understanding of the results, Pöyry would recommend the following next steps for the successful establishment of marine biofuels.

1. Additional analysis
   • Regional assessment of biomass costs and supply risks

2. Project consortium decision base
   • Agreement on key target assortments as feedstock for marine biofuel production

3. Further investigations for scaling up biomass supply
   • Level of integration into the biofuel sourcing supply chain
   • Selection of target catchment areas on country level
   • Assessment of most promising assortments and catchment areas in the identified target countries
   • Detailed assessment of target countries and catchment areas:
     – Regional specific biomass mix and sustainability assessment
     – Supply demand balance and outlook
     – Biomass supply chains, price assessment and forecast
   • Detailed impact assessment of up-scaling bioenergy production
   • Matching with existing global port infrastructure and fuel hubs
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

SUPPLY MARKETS – WOODY BIOMASS
Main assortments coming from forests are sawlogs, pulpwood and fuelwood. Utilization of forest (harvesting) residues is globally in a very early stage.

- **Forest residues**
  Tops and branches and wood with defects making it unusable for industrial (material) use.

- **Pulpwood**
  Lower quality wood or wood of smaller diameter. Used for pulp, particleboard and MDF production.

- **Sawlogs/ Veneer logs**
  High quality wood utilized for sawmills, veneer and OSB production.

- While forest residues may already be used as fuelwood, fuelwood may also contain wood suitable for pulp, panel or sawmill industries
- Stump extraction is not considered in the calculations
FOREST INDUSTRY RESIDUES

Main sawmilling by-products are sawdust, chips and bark. In pulp mills bark, different ‘waste’ liquors and sludges are typical by-products.

Chips and Dust
Chips and dust are utilized by panelboard producers, pellet industry and for bioenergy production. Sawmills often have integrated bioenergy plants.

Pulping liquors and sludges
Depending on pulp (mechanical, semi-mechanical, chemical) and specific process different cooking liquors and sludges are generated (e.g. black liquor). Typically these liquids are used internally for energy production. Pulp industry is currently looking for value added utilization (biofuels/-materials).

Bark
Debarking of roundwood results in large quantities of bark at forest industry sites. Main purpose of bark is in energy production. Only very limited amounts can be used by panel industry. Pellet industry can utilize bark when producing industrial pellets. Residential pellets do not contain bark.
FOREST BIOMASS CALCULATION

For forecasting woody biomass potentials the change in forest area and consumption are taken into account. Global wood trade is included as well. For each region the following methodology applies:

2010

- Forest types
  - Primary
  - Modified natural
  - Semi-natural
  - Productive plantation
  - Protective plantation

- Forest area distribution
- Increment/AAC

2015 - 2020

- Change in forest area
- Increment/AAC

- Forest residues
- Harvestings

- Forest product production

- Consumption/trade forecast

- Woody industrial residues

Hardwood/Softwood
- Sawlogs
- Pulpwood

Base data from official or literature sources

Calculation increment

Calculation forest primary production/harvest

Calculation industrial residues
ASSUMPTIONS FORESTRY AND FOREST INDUSTRY

Assumptions on growth rates and changes over time used for forecasting world biomass potentials.

- Data on forest area, distribution and composition represents the last available data and is used as base value for the forecasts.
- For the forecasts the 5 year mean value of the forest product production is used as base value. This is to account for short term variations in production.
- Future forest area by region is based on data from Buongiorno et al. (2012). Baseline projections on GDP technology and world development are designed in accordance with the Scenario B2 of the Intergovernmental Panel on Climate Change (IPCC). Scenario B2 is an intermediate scenario with moderate forecast on growing globalization, incomes and population.
- It is assumed that forest loss will mainly occur in primary forests while forest growth will take place in commercially operated forests or dedicated plantations.

Buongiorno et al. (2012)
GLOBAL WOOD HARVEST 2000-2010

Global wood harvest has been relatively constant in the last decade. In Africa majority of harvest is for fuelwood. Decrease of harvesting in North America is due to calamities in Canada and economic crisis in USA, which is recovering again.
Around 50% of the total harvest are used for direct energy generation. Also the by-products of forest industry are partly used for energy production. In total wood is a major global bioenergy source already today.
GLOBAL INDUSTRIAL WOOD PRICES

Industrial wood prices have shown a slight decrease in real terms since the 1960s. Since 2000 price level has stabilized and shows a slight increase.

Real US$/m³ (1997 US$)

Up to 2006 according to Buongiorno et al. 2012; from 2007 continued with Pöyry real term price development of selected global regions
GLOBAL ENDPRODUCT PRICES

Panel industry and paper industry have seen a steady decline in prices for their products. In some assortments revenues have reduce by half. Enterprises are adjusting and moving towards countries with competitive advantages.

According to Buongiorno et al. 2012
FOREST SUPPLY MARKETS OVERVIEW

World forest area has been declining in the past though this trend slowed in some regions.

- Africa showed a decline in forest area in the past nevertheless this trend has slowed in the past twenty years. Growing supply is now primarily based on the establishment of fast growing plantations. Fuelwood utilization for domestic uses has increased due to rising population and will continue to exceed supply by far.
- Asia and Pacific lost forest area until the year 2000. Since then reforestation efforts from China, India and Vietnam result in a net growth primarily based on fast growing plantations. Area of primary forests declined. In the Near East forest area is relatively small but stable.
- In Latin America and Caribbean the forest area declined in the past two decades mainly due to forest conversion to agricultural land. The region's primary forests are mainly located in inaccessible areas and constitute the world largest resource of primary forests. These primary forest are excluded from supply considerations to secure natural biodiversity. Growing supply volumes are based on fast growing plantations. Still large and growing quantities of wood are removed for fuelwood.
- North America showed a slight increase in forest area from 1990 to 2010. Plantations originally established for the forest industry are currently an attractive base for pellet industry investments. Wood fuel plays a minor role up to now.
TYPICAL BUSINESS MODELS FOR BIOMASS SOURCING

Different sorts of ownership and different management types require adapted sourcing strategies.

**Partnership with existing forest industries**

- Can provide good control over the wood flow and supply chain
- Gives access to the extensive know-how of the wood processing industries in wood sourcing and procurement
- Opportunity to engineer highly optimised fibre flows for all raw material fractions
- Emergence of new dedicated bioenergy processors e.g. pellet production

**Long-term biomass supply contracts**

- No direct capital investment is required and flexibility to react on biomass-market can be maintained
- New entrants in the forestry and wood industry sector are more open to long term off-take agreements e.g. pellet plants, forest funds

- Integrated sawmilling companies are less suited for supply partnerships since all industrial residues usually are consumed internally e.g. for pulp production
- Non-integrated sawmilling players typically have existing relationships with traditional biomass end users in pulp and wood-based panels

- No direct control over the wood flow.
- Sustainability of supply partners to be approved
- Forest industry companies as well as private forest resource owners are typically reluctant to enter into long term supply contracts
BUSINESS MODELS FOR SECURING BIOMASS SUPPLY

Owing forest resources provide a very high level of security and is also a good way for reducing the risk exposure to rising wood prices on the market.

Purchase or Lease of Existing Forest Resources

- Interesting opportunity in Eastern Europe, Latin America and Africa where prices for forest land are comparatively low and assets of a viable size can be purchased
- Reduced risk exposure to rising wood prices on the market
- Interesting investment option by itself

Establishment of New Forest Resources

- Offers potential opportunities for higher rates of return than the purchase of existing assets - valuations are currently robust.
- Interesting countries for new forest plantations can be found especially in Latin America and Sub-Saharan Africa.
- Purpose build energy resources – optimisation possible towards low grade biofuel production and carbon management
- Requires capital investment and partner with necessary technical forest expertise for managing the forest assets
- Exposure to issues associated with land ownership, e.g. social and environmental issues
- Biomass supply would not be immediately available.
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

SUPPLY MARKETS – AGRICULTURAL BIOMASS
Future forecast of residue potentials is based on current productivity and area of production. Predicted changes over time are used to adjust the future residue potentials. For each region the following methodology applies:

**Change in productivity**
Time series from Ludena et al. (2006) were used who estimated future productivity on a regional basis.

**Change in agricultural area**
While in some regions agricultural area is expanding others are losing arable land due to desertification and urbanization. Reginal forecasts from BMVBS (2010) were used.

**Straw grain ratios**
Modern cultivars are optimized for crop yield and a low residue production. Dynamic residue yield equations take this into account.
ASSUMPTIONS AGRICULTURE

Assumptions on growth rates and area change over time and are used for forecasting world biomass potentials.

- For the forecasts the 5 year mean value is of yield, area harvested, etc. is used as starting point.
- Productivity growth by region is forecasted based on Ludena et al. (2006) that calculated the total productivity factor based on historical input values of machinery, labor, land and fertilizer inputs. Up-catching of different regions to technology standards of more developed countries is factored in by using directional distance functions and the Malmquist Index.
- Growth of land and utilization of fallow land by region is in accordance with published values from BMVBS (2010), where forecasts of developments for the different world regions are included. Area growth of agriculturally used land is triggered by deforestation as well as melioration and irrigation of land and utilization of fallow land. Decline of arable land due to degradation and urbanization is factored in the growth rates.
- Distribution of relative land utilization per crop is assumed to be constant over time.
AGRICULTURAL RESIDUES

Agricultural residues from cereals, sugar cane and oil palm represent major biomass flows.

Cereal straws and rice husks
Cereal straws are used as animal bedding or animal feed. Straw is also left on the fields, mulched or burned due to phytosanitary concerns. Rice husks (hulls) is separated in rice milling. It's burned or used as low quality animal feed.

Sugar cane (tops and leaves)
To increase efficiency of harvesting the fields are burned prior to harvesting. Residues can also be left in the fields, mulched or utilized as animal feed. Industrial collection and utilization is in an early stage.

Sugar cane (bagasse)
Bagasse are the sugar cane stalks crushed during juice extraction. Main utilization is internal firing. Bagasse can be used for panel boards, pulp production or as animal feed. 2nd generation bioethanol is in a very early stage.
AGRICULTURAL RESIDUES (CONT’D)

Palm oil is obtained from the mesocarp or fleshy part of the fruit (45-55% oil), palm kernel oil is obtained from the seed in the fruit (50% oil). Both have significant commercial value.

Stems and fronds of oil palms
A typical rotation cycle of an oil palm plantation is 25 years. Then stems are cut down and the plantation is replanted. Fronds are cut every year. Stems are seldom used for production of sawnwood due to high silica content. Fronds remain for nutrient cycling.

Empty fruit bunches (EFB), fruit fibres, palm kernel shells
Typical residues from oil palm plantations are the empty fruit bunches and mesocarp fibres. While the fibres are burned or traded (e.g. to Italy to a larger extent) the EFB are composted to a large share.

Palm oil mill effluent
Palm oil mill effluent is the residue from screening the palm oil. It’s characterized by a large water content. Typically POME is stored in ponds until organic load has reduced remainings are then discharged to rivers. Recently biogas is generated from POME.
OIL PALM PLANTATIONS

Globally oil palm plantation resources are estimated to be 15.5 million ha at present. Nearly 94% of these resources are located in five countries (Indonesia, Malaysia, Thailand, Columbia and Nigeria). Indonesia and Malaysia alone constitute 83% of global plantations.

Indonesia: 7.8 million ha (51%)
Malaysia: 5 million ha (32%)
Nigeria: 0.3 million ha (2%)
Thailand: 0.7 million ha (5%)
Columbia: 0.6 million ha (4%)

Other countries to consider:
Ghana
Guinea
Democratic Republic of Congo
Ecuador
Papua New Guinea
Honduras
Brazil
CRUDE PALM OIL (CPO) MILL BIOMASS RESIDUES

Traditionally biomass residues from the CPO mill have been treated as waste. Over the last few decades numerous successful (and some unsuccessful) end uses have emerged.

Current end use applications in use or under serious consideration

- Methane gas and electricity generation, CDM, fertiliser, bio-based chemicals
- Fertiliser, pellets, bioethanol, bio-oil, pulp, biocomposites, long fibre, mattress liner/stuffing, MDF, activated carbon
- Electricity generation, fertiliser
- Biomass for export/energy generation/, roading material, activated carbon

FFB = Fresh fruit bunches
CPO = Crude palm oil
POME = Palm oil mill effluent
EFB = Empty fruit bunches
PK = Palm kernel
PKS = Palm kernel shells
GLOBAL HARVEST AGRICULTURE

Global harvest of agricultural products has increased in the last decade. Largest growth could be observed in Latin America and Asia, which count for approx. 70% of world production.

FAOSTAT 2012
Agro-based fuel production can be based on main/refined crops and residues from harvesting/processing of the crops. The following analyses focus only on processing residues and residues not suitable for food production.
AGRICULTURE SUPPLY MARKETS

World food prices in real terms have declined in the past. Price volatility is main threat to world food security.

- Sinking real term prices for agricultural products and highly subsidized agricultural industries from developed countries had made agriculture unattractive. Consequently higher food prices had been promoted by international organizations in the past.
- During the food price crisis from 2007 – 2009, that initially was triggered by bad harvests, countries enforced export bans and other export restrictions to ensure supply for domestic markets. This combined with global recession had major impact on global food security.
- To increase productivity in a sustainable manner additional investments into agriculture are needed. A high but stable absolute price for agricultural commodities is needed to attract the required investments.
- Price volatility is seen as major threat for global food security – poorer populations can adjust to long term developments while price peaks have severe impact.
AGRICULTURE SUPPLY MARKETS CASE EXAMPLES

Success of land expansion is dependent on clear structure of property rights, support from local authorities and research.

- Land expansion in Latin America & Caribbean has been taken place on two types of land – former forests (for livestock ranching) and savannas (cerrado) for soy or other crops. The utilization of the savannas was only made possible by research. Acid soils formerly unsuitable for agricultural production are now made accessible. Use of conservation tillage and appropriate varieties increase productivity.
- In Southeast Asia agriculture has expanded significantly in countries such as Thailand, Vietnam, Malaysia and Indonesia. Here large areas have been cultivated for oil palm and rice production. Smallholders have been actively engaged in this process with positive effects on poverty reduction, gradual increases of farm size and productivity. These productivity increases were not restricted to large scale land acquisitions but explicitly smallholders did participate.
- Area Expansion in Africa has been based on smallholder initiatives as policy distortions like export bans and low public investment have limited investment into agriculture. Attempts of large scale farming in Sudan, Tanzania and Zambia were not successful. Especially neglect of existing land rights undermines the initiatives additionally to bad management and poor technology. Yields remain low.
- Development in Eastern Europe and Central Asia has been mainly driven by large farms. These were better able to deal with financing, technology and infrastructure constraints. Nevertheless the total areas sown in Russia are still some 30 Million ha below former Soviet times. These areas have been turned to pastures or fallow.
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

RESULTS – BIOMASS POTENTIALS
GLOBAL FOREST RESOURCE BY TYPE OF FOREST

Latin America holds some 24% of the global forest resource. Most of this is native forest are located in the Amazonian region.

Source: FAO/Pöyry
EXTENT OF PLANTATION RESOURCES

The estimated global plantation forest area is 156 million hectares, of which some 30 million hectares is estimated by Pöyry “to qualify” as industrial fast-growing plantations.

- Plantations cover almost 160 million hectares. Some 120 million hectares are classified as productive plantations and the balance consists of protective plantations.
- Industrial fast-growing plantations have been separated from other productive plantations based on the following criteria:
  - established totally or partly for production of wood for industry mainly as sawlogs, veneer logs or pulpwood
  - mean annual increment (MAI) exceeding 12 m3/ha/a
- Industrial fast-growing plantations play a larger role in global wood supply than what their share of total forest area would suggest.

Source: FAO/Pöyry
FOREST BALANCE WORLDWIDE

Forest increment and residue volumes are slightly increasing. Demand is primarily increasing for fuelwood. Substantial surplus of forest biomass exists globally.

Source: Pöyry
Fuel wood consumption exceeds increment substantial in Africa and Rest of Asia. Highest surplus of increment and residues is in North America, Russia, Europe and Latin America.

Source: Pöyry
FOREST BALANCE 2015

Fuel wood consumption grows significantly in Africa and Rest of Asia. Increase of increment is primarily in regions with fast growing plantation like Latin America, Rest of Asia and Oceania.

Source: Pöyry
Growing demand meets decreasing increment in Africa, Russia and North America. Parallel increase of demand and supply are in Latin America, China, Europe and Rest of Asia. Oceania shows substantial increase of increment without corresponding growth of demand.

Source: Pöyry
Forest harvesting residues are globally in an early stage to be utilized for energy production. Sawmill residues are a major source for the pulp and panel industry. Increased utilization arises from the pellet industry. Pulpmill residues are typically fully used for internal energy production. Several R&D projects target on high value added utilisation as biofuel or biomaterials.
Corresponding to the forest harvesting the residue production is largest in North America, Europe and Latin America. Sawmill and pulpmill residues also have the largest potential in these regions.

Source: Pöyry
RESIDUE PRODUCTION 2015

Forest residues and sawmill residues develop in line with the annual harvest volumes in the respective countries. Largest growth in pulpmill residue production can be observed in China.

Source: Pöyry
RESIDUE PRODUCTION 2020

Pulpmill residues in North America and Japan keep decreasing while China, the Rest of Asia and Latin America increase the production of pulpmill residues.

Source: Pöyry
From 2010 to 2020 onwards world residue production will grow for approximately 240 million oven dry tons.

Source: Pöyry
AGRICULTURAL RESIDUES 2010

Displayed is the technical potential of residues without any restrictions on availability. Majority of residues comes from cereal straw. Residues from sugar cane processing and palm oil industry on a larger scale are only available in Latin America, Asia and Africa.

Source: Pöyry
Substantial growth of agricultural residues can be expected in Asia, America and Oceania. Europe and Russia show only slight increase.
Substantial growth of agricultural residues continues in Asia (focus on rice, wheat, oil palm and sugar cane) and America (North: maize, South: sugar cane, maize). Europe and Russia show slight increase focused on cereal straw.

Source: Pöyry
IMPACTS OF GLOBAL MEGATRENDS ON BIOMASS AVAILABILITY

- An increasing population is to be nourished
- Change of diet results in larger demand for feed
- Impact of financial crisis
- Increase of investments in land/resources
- Managing climate change (Durban, Copenhagen, Rio)
- Land use change
- Impact of oil (liquid biofuels) and coal (utilities) price on biomass demand
- Impact of Co-firing
- New materials
SUSTAINABILITY AND CERTIFICATION SYSTEMS

Sustainability was first mentioned in the 18th century and further developed from the United Nations and the Brundtland-Commission (1983). To control the observance of this concept, several certification systems were established.

The three pillars of sustainability

- Social
  - Bearable
  - Equitable
- Environment
  - Sustainable
  - Viable
- Economic

Major certification systems

- FSC
- SFI
- PEFC
- BON SUCRO
- GLOBAL G.A.P.
- RSPO
- ISCC
- RSB
## CERTIFICATION SYSTEMS

Synthesis of social, ecological, economic and general criteria. These were derived from over 100 published sustainability sub-criteria.

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<th>Ecological criteria</th>
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<td>• Preservation of existing sensitive ecosystems</td>
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<td>• Rights of children, women, indigenous people and discrimination</td>
<td>• Conservation of biodiversity</td>
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<td>• Access to resources ensuring adequate quality of life</td>
<td>• Conservation and improvement of soil fertility</td>
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<td>• Food and energy supply safety</td>
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<td>• Capacity building</td>
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<td>• Community (institutional) well-being</td>
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<td>• Fair trade conditions</td>
<td>• Waste management</td>
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<td>• Compliance with laws and international agreements</td>
</tr>
<tr>
<td>• Long term prospective</td>
<td>• Traceability</td>
</tr>
<tr>
<td>• Strength and diversification of local economy</td>
<td>• Avoidance of leakage effect</td>
</tr>
<tr>
<td>• Reliability of resources</td>
<td>• Strengthening the role of non-governmental organizations</td>
</tr>
<tr>
<td>• Yields</td>
<td>• Improvement of conditions at local level</td>
</tr>
<tr>
<td>• No blocking of other desirable developments</td>
<td></td>
</tr>
</tbody>
</table>
IMPACT SUSTAINABILITY CRITERIA ON BIOMASS POTENTIALS

Careful attention has to be paid to sustainable operations in forestry and agriculture. Nevertheless maintaining the productive capacities of soil and society results in a reduction of available biomass potential – in the short run.

• Observance of the certification scheme regulations may increase productivity and profitability of operations due to implementation of management plans and best practices experiences (especially in tropical countries).
• Reduction of potential is mainly due to the exclusion of areas of the calculations (environmental issues, unsettled land rights).
• Demand for certified products is main driver for future development. Costs for certification and additional costs for improved practices are hurdles for implementation.
• What is economical feasible is mainly dependent on the market price for the products. Best example is forest residue utilization in Central Europe triggered by green energy feed in tariffs.
**ADDITIONAL BENCHMARK-CRITERIA FOR CERTIFICATION SCHEMES**

Certification does not only differ in the type and definitions of “sustainability” but also in administrative and structural items.

- Public transparency
- Involving stakeholders in processes
- Treatment of complaints and claims
- Third party control
- Required competences of auditors
- Frequency and type of auditing / validity
- Procedures and sanctions for non-compliance
- Group certification
- Traceability and the chain of custody
- Level of recognition and affiliation of the system
- Cost structures (membership fee, producer fee, etc.)
GLOBAL FOREST CERTIFICATION OVERVIEW

By mid 2012 the global area of certified forests endorsed by the two international leading frameworks – FSC or PEFC – amounted to 394 million ha. The recent growth in certified forest area has taken place in Russia and Northern America. Almost 90% of the certified forest area is in Northern Hemisphere.

Certification by Region*

*The figures do not take into account overlap between different certification schemes

Source: Pöyry

Certification by Region

Japan
China
Rest of Asia
Africa
Oceania
Latin America
Western Europe
Russia
Eastern Europe
Nordic countries
North America

Million ha

0
200
400

FSC-area
(June 2012; 1 000 ha)

PEFC-area
(March 2012; 1 000 ha)
CURRENT AGRICULTURAL CERTIFICATION SYSTEMS

Global G.A.P.
- Private sector body formed in 1997, sets voluntary standards for the certification of agricultural products worldwide.
- GAP is a pre-farm-gate standard: the certification covers the process of the certified product from before the seed is planted until it leaves the farm. Other standards are recognized to cover the remaining parts of the process chain.

SAN/Rainforest Alliance
- A coalition of non profit, independence conservationist organizations, founded 1987, promoting the social and environmentally sustainability of agricultural activities. Certified crops include e.g. soy, sugarcane, sunflower, palm oil or coffee.
- The main focus lies on tropical regions.

The Better Sugarcane Initiative (BSI)/BonSucro
- A collaboration, founded 2011, of sugar retailers, investors, traders, producers and NGOs who committed to sustainable sugar by establishing principles and criteria that are applied in the sugar growing regions of the world through regionally specific strategies and tools.
- Aim is to certify one third of the total sugarcane production until 2020.

The Roundtable on Sustainable Palm Oil (RSPO)
- Formed in 2004 with the objective promoting the growth and use of sustainable oil palm products through credible global standards and engagement of stakeholders.

ISCC - International Sustainability & Carbon Certification
- The ISCC is one of the most extensive certification system up to now (Base study on sustainability criteria by Meo-Consulting).
- As first certification system ISCC was approved after the German Biofuel-Sustainability-Act in 2010.
- Still a very limited relevance in terms of certified areas. From 1429 awarded certifications (as of June 2012) only 20 were given to farms/plantations.
ISCC - INTERNATIONAL SUSTAINABILITY & CARBON CERTIFICATION

Explanations of objectives and working methods of the ISCC.

- ISCC has developed rules and standards. It notifies the different certification bodies.
- The objectives of ISCC are the establishment of an internationally oriented, practical and transparent system for the certification of biomass and bioenergy.
- ISCC is oriented towards
  - Reduction of greenhouse gas emissions
  - Sustainable use of land
  - Protection of natural biospheres
  - Social sustainability
- Every single step of the value chain from the production over the transportation to warehouse and conversion units, till the final sale is covered by the ISCC.
- So the whole producing process from farm to final consumer is monitored.

Source: ISCC 2012
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

SUSTAINABILITY RANKING
BARRIERS TO SCALE

To evaluate a region’s potential for up scaling biomass use, it is necessary to perform a country by country approach. For a comprehensive picture all three aspects of sustainability were analyzed.
INDEXES – ENVIRONMENT

The single indexes used for the sub-aspects of the environment index.

<table>
<thead>
<tr>
<th>Index</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAZ</td>
<td>The Global Agricultural Zones measure the area of suitable and very suitable land per country in relation to the total area available [%]. This does take into account length of growing period, fertility of soils, precipitation, etc.</td>
<td>[1] IIASA (2000)</td>
</tr>
<tr>
<td>GHG emission with LUCF per capita</td>
<td>Scores the country’s by their greenhouse gas emissions per capita with LUCF compared to the intended emissions of the 2°C warming goal of the UN [CO2 equivalent]</td>
<td>[5] WIR (2005)</td>
</tr>
<tr>
<td>LUCF per capita</td>
<td>Scores the country’s by their greenhouse gas emissions per capita produced by LUCF [CO2 equivalent]</td>
<td>[6] WIR (2005)</td>
</tr>
<tr>
<td>Water stress</td>
<td>Total freshwater withdrawn in a given year, expressed in percentage of the total actual renewable water resources (TARWR) [%]</td>
<td>[7] AQUASTAT (2012)</td>
</tr>
<tr>
<td>Agricultural water use</td>
<td>Amount of water withdrawn by the agricultural sector as a percent of all the water withdrawn by the three main water withdrawing sectors (agriculture, municipalities, industry). [%]</td>
<td>[8] AQUASTAT (2012)</td>
</tr>
</tbody>
</table>
# INDEXES – ECONOMY

The single indexes used for the sub-aspects of the economy index.

<table>
<thead>
<tr>
<th>Index</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic Infrastructure Index</td>
<td>Quality of trade and transport related infrastructure (roads, railroad, ports, information technology)</td>
<td>[9] Worldbank (2012)</td>
</tr>
<tr>
<td>Logistic Competence Index</td>
<td>Competence and quality of logistics services (e.g. transport operators, custom brokers)</td>
<td>[10] Worldbank (2012)</td>
</tr>
<tr>
<td>Corruption Index</td>
<td>The Corruption Index scores country's on how corrupt their public sectors are seen to be.</td>
<td>[12] Transparency international (2011)</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>An approximation of the value of goods produced per person in the country, equal to the country’s gross domestic product divided by the total number of people in the country [USD]</td>
<td>[13] Worldbank (2012)</td>
</tr>
<tr>
<td>Fertilizer consumption</td>
<td>Total consumption of non bio fertilizer per country [t]</td>
<td>[14] FAOSTAT (2009)</td>
</tr>
<tr>
<td>Prohibitive tariffs</td>
<td>Measures if any sort of export taxes or duties have to be payed [yes or no]</td>
<td>[16] Worldbank (2009/2010)</td>
</tr>
<tr>
<td>Sanctions</td>
<td>Scores countries by being currently sanctioned by the EU and/or USA [yes or no]</td>
<td>[17] BSCN (2012)</td>
</tr>
</tbody>
</table>
## INDEXES – SOCIAL

The single indexes used for the sub-aspects of the social index.

<table>
<thead>
<tr>
<th>Index</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stability</strong></td>
<td>Failed State Index</td>
<td>The index’s ranks are based on twelve indicators of state vulnerability: demographic pressures, refugees and IDPs, group grievance, human flight, uneven development, poverty and economic decline, legitimacy of the state, public services, human rights (excluded to avoid double counting), security apparatus, factionalized elites, external intervention</td>
</tr>
<tr>
<td>Human Rights Index</td>
<td>The Human Rights Index measures the degree of lack of protection or noncompliance of the obligations of states in regard to human rights and the International Humanitarian Law</td>
<td>[18] The Fund for Peace (2012)</td>
</tr>
<tr>
<td>HDI without GDP</td>
<td>The Human Development Index measures the development in each country by scoring following criteria’s: life expectancy at birth, mean years of schooling, expected years of schooling, gross national income per capita (excluded to avoid double counting)</td>
<td>[19] UNDP (2011)</td>
</tr>
<tr>
<td>Global Hunger Index</td>
<td>The Global Hunger Index scores countries on: proportion of undernourished in the population (%), prevalence of underweight in children under five years (%), under five mortality rate (%)</td>
<td>[20] IFPRI (2010)</td>
</tr>
<tr>
<td><strong>Humanity</strong></td>
<td>Labor conditions</td>
<td>Measuring the rigidity of hiring and redundancy and working hours (to be done)</td>
</tr>
<tr>
<td>Gender inequality Index</td>
<td>A composite measure reflecting inequality in achievements between women and men in three dimensions: reproductive health, empowerment and the labour market.</td>
<td>[19] UNDP (2011)</td>
</tr>
<tr>
<td>Labor conditions of children</td>
<td>Scoring the country by percentage of children aged 5-14 engaged in child labour</td>
<td>[22] UNICEF (2010)</td>
</tr>
</tbody>
</table>
NORMALIZATION AND RANKING

Methods of combining the indexes

- For a better comparability all indexes were normalized to a scale from 0 to 1, then weighted and summarized to a lead index.

- Extreme outliers were excluded from the normalization and set to maximum/minimum values.

1 = Best rating
0 = Worst rating
SUSTAINABILITY OF UP-SCALING BIOMASS SOCIAL VS. ECONOMIC RATING

In general upscaling of biomass supply looks feasible in all global regions from social perspective. Country by country valuation would especially be recommended in selected areas of Africa, Asia, Russia and South America.

Remark: Size of bubble is based on biomass potential.
ECONOMIC RATING – EXPLANATION

Through the regional aggregation of indices data was generalized. A country by country ranking is recommended. Assignment of regions is found in the glossary.

- Africa has seen the largest rise in agricultural investments in regard to absolute numbers. Nevertheless results all other aspects of the economic rating indicate large problems in conducting business.
- Asia is also upcatching when it comes to agricultural investments. All other indicators are slightly below average, except corruption with a ranking below standard.
- Pacific & Oceania is showing an average performance. Fertilizer usage is below average. Results of Australia and New Zealand are clearly above average, nevertheless other countries of the regions are not that far developed.
- Europe, Eastern Europe and Russia show the smallest increase in agricultural investments, but on a very high level. Absolute fertilizer usage is below average.
- North America is over-performing in all fields except growth in agricultural investment.
- South America is showing equal performance with Asia, except the rankings concerning prohibitive tariffs and sanctions where South America is showing better ratings.
SOCIAL RANKING – EXPLANATION

Through the regional aggregation of indices data was generalized. A country by country ranking is recommended. Assignment of regions is found in the glossary.

- Africa is ranking worst in all social indices. Only exception is the human rights index where Africa and Asia are rating equally low.
- Asia is slightly ranking better than Africa in all categories, except human rights, where equal rankings with Africa were achieved. Asia is average when it comes to the rigidity of employment.
- Pacific & Oceania is showing above average performance in the rigidity of employment and best rankings in terms of hunger and child labor (together with North America).
- Europe, Eastern Europe and Russia are showing best performances after North America, exception is the rigidity of employment where the region is ranking below average.
- North America is showing best performance in all categories.
- South America is ranking slightly better than Asia except the rigidity of employment and gender equality. Human development and Hunger are on or slightly above world average.
SUSTAINABILITY OF UP-SCALING BIOMASS ECOLOGIC VS. ECONOMIC RATING

In general up-scaling of biomass supply looks feasible in all global regions from ecological perspective. Country by country valuation would especially be recommended in selected areas of Asia, Oceania, Africa, Russia and South America.

Remark: Size of bubble is based on biomass potential.
ECOLOGICAL RANKING – EXPLANATION

Through the regional aggregation of indices data was generalized. A country by country ranking is recommended. Assignment of regions is found in the glossary.

- Africa is ranking worst in deforestation and faces large problems regarding land use change emissions. Agriculture does already today utilize large shares of available water resources. Nevertheless large areas are technically suitable or very suitable thus making the land interesting in principal. Greenhouse gas emissions are very low.
- Asia has large degraded lands and is facing severe water stress. At the same time large shares of the available water are utilized in agriculture. Land use change, deforestation and green house gas emissions are other areas where the region is rating below standard.
- Pacific & Oceania are rating worse than Asia in the availability of suitable soils, and has additionally the largest share of land that are already degraded. Deforestation, especially in Australia is a problem. Overall water stress is a problem, as agriculture utilizes large share of the resource.
- Europe, Eastern Europe and Russia are rating best in suitable soils, land use change and the share of degraded land. Deforestation is a minor problem. In the categories emissions and water stress the region is on average.
- North America and Europe have comparable results. Nevertheless North America is largest emitter of greenhouse gases and has less favorable growing conditions.
- South America is ranking worst when it comes to land use change and deforestation (comparable results with Africa). Overall suitability of land is good and water is available but water usage in agriculture is high. Overall green house gas emissions ranking is above average.
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

REGIONAL RANKING
REGIONAL BENCHMARK – EXPLANATION

The regional benchmark has been realised taking into account data collected during the study and Pöyry’s expert opinion

- **Biomass potential**: The availability of the respective material in one region was compared to the maximum single availability that was achieved. Adjustment for special circumstances.

- **Maturity of biomass handling**: Rating depending on Pöyry’s view on maturity of biomass handling in the region

- **Biomass controversy and up-scaling potential**: The ranking from the biomass sustainability ranking and Pöyry’s view on up-scaling potential were rated with a weight of 70% to 30%.
## REGIONAL BENCHMARK

<table>
<thead>
<tr>
<th>Region</th>
<th>Assortment</th>
<th>Cumulative biomass potential 2020 [M odt]</th>
<th>Biomass potential 40,0%</th>
<th>Maturity of biomass handling 30,0%</th>
<th>Biomass controversy and upscaling potential 30,0%</th>
<th>Result 100,0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>Industrial roundwood</td>
<td>389</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>3,0</td>
</tr>
<tr>
<td>North America</td>
<td>Cereal Straw/Husks</td>
<td>1,023</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>3,0</td>
</tr>
<tr>
<td>North America</td>
<td>Forest industry residues</td>
<td>1,168</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>3,0</td>
</tr>
<tr>
<td>Europe</td>
<td>Forest residues</td>
<td>1,250</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,9</td>
</tr>
<tr>
<td>South America</td>
<td>Sugar cane residues</td>
<td>1,432</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,8</td>
</tr>
<tr>
<td>South America</td>
<td>Industrial roundwood</td>
<td>1,883</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,8</td>
</tr>
<tr>
<td>North America</td>
<td>Forest residues</td>
<td>1,966</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,7</td>
</tr>
<tr>
<td>Asia excl. China</td>
<td>Palm oil residues</td>
<td>2,206</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,6</td>
</tr>
<tr>
<td>Asia excl. China</td>
<td>Cereal Straw/Husks</td>
<td>3,252</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,6</td>
</tr>
<tr>
<td>Russia</td>
<td>Cereal Straw/Husks</td>
<td>3,399</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,6</td>
</tr>
<tr>
<td>China</td>
<td>Cereal Straw/Husks</td>
<td>4,020</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,6</td>
</tr>
<tr>
<td>Europe</td>
<td>Industrial roundwood</td>
<td>4,436</td>
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<tr>
<td>Europe</td>
<td>Cereal Straw/Husks</td>
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<td>40,0%</td>
<td>30,0%</td>
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</tr>
<tr>
<td>Europe</td>
<td>Forest industry residues</td>
<td>4,972</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,5</td>
</tr>
<tr>
<td>Russia</td>
<td>Industrial roundwood</td>
<td>5,305</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,4</td>
</tr>
<tr>
<td>South America</td>
<td>Forest industry residues</td>
<td>5,353</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,4</td>
</tr>
<tr>
<td>Pacific &amp; Oceania</td>
<td>Industrial roundwood</td>
<td>5,411</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,4</td>
</tr>
<tr>
<td>Asia excl. China</td>
<td>Sugar cane residues</td>
<td>5,537</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,3</td>
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<tr>
<td>South America</td>
<td>Cereal Straw/Husks</td>
<td>5,853</td>
<td>40,0%</td>
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<td></td>
<td>2,1</td>
</tr>
<tr>
<td>Pacific &amp; Oceania</td>
<td>Forest residues</td>
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<td>40,0%</td>
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<tr>
<td>China</td>
<td>Forest industry residues</td>
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<td>40,0%</td>
<td>30,0%</td>
<td></td>
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</tr>
<tr>
<td>South America</td>
<td>Forest residues</td>
<td>5,972</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,0</td>
</tr>
<tr>
<td>China</td>
<td>Sugar cane residues</td>
<td>5,999</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,0</td>
</tr>
<tr>
<td>Pacific &amp; Oceania</td>
<td>Sugar cane residues</td>
<td>6,009</td>
<td>40,0%</td>
<td>30,0%</td>
<td></td>
<td>2,0</td>
</tr>
</tbody>
</table>

**Legend:**
- **Positive > 2.5**
- **Neutral = 1.5 - 2.5**
- **Negative < 1.5**
## REGIONAL BENCHMARK CONT’D

<table>
<thead>
<tr>
<th>Region</th>
<th>Assortment</th>
<th>Cumulative biomass potential 2020 [M odt]</th>
<th>Biomass potential</th>
<th>Maturity of biomass handling</th>
<th>Biomass controversy and upscaling potential</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Russia</td>
<td>Forest residues</td>
<td>6.092</td>
<td>40,0%</td>
<td>30,0%</td>
<td>30,0%</td>
<td>1,9</td>
</tr>
<tr>
<td>Russia</td>
<td>Forest industry residues</td>
<td>6.130</td>
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<td>Asia excl. China</td>
<td>Forest industry residues</td>
<td>6.220</td>
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<td></td>
<td></td>
<td>1,9</td>
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<tr>
<td>Pacific &amp; Oceania</td>
<td>Forest industry residues</td>
<td>6.230</td>
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<td></td>
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<td>1,7</td>
</tr>
<tr>
<td>Pacific &amp; Oceania</td>
<td>Palm oil residues</td>
<td>6.230</td>
<td></td>
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<td>1,6</td>
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<tr>
<td>China</td>
<td>Industrial roundwood</td>
<td>6.363</td>
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<td></td>
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</tr>
<tr>
<td>China</td>
<td>Forest residues</td>
<td>6.381</td>
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<tr>
<td>North America</td>
<td>Sugar cane residues</td>
<td>6.389</td>
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<tr>
<td>North America</td>
<td>Palm oil residues</td>
<td>6.389</td>
<td></td>
<td></td>
<td></td>
<td>1,4</td>
</tr>
<tr>
<td>Europe</td>
<td>Sugar cane residues</td>
<td>6.389</td>
<td></td>
<td></td>
<td></td>
<td>1,4</td>
</tr>
<tr>
<td>Europe</td>
<td>Palm oil residues</td>
<td>6.389</td>
<td></td>
<td></td>
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<td>1,4</td>
</tr>
<tr>
<td>South America</td>
<td>Palm oil residues</td>
<td>6.400</td>
<td></td>
<td></td>
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<td>1,4</td>
</tr>
<tr>
<td>Russia</td>
<td>Sugar cane residues</td>
<td>6.400</td>
<td></td>
<td></td>
<td></td>
<td>1,4</td>
</tr>
<tr>
<td>Russia</td>
<td>Palm oil residues</td>
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</tr>
<tr>
<td>China</td>
<td>Palm oil residues</td>
<td>6.400</td>
<td></td>
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<tr>
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<td>Industrial roundwood</td>
<td>6.653</td>
<td></td>
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<tr>
<td>Africa</td>
<td>Forest residues</td>
<td>6.670</td>
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<tr>
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<td>Industrial roundwood</td>
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<td></td>
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<tr>
<td>Africa</td>
<td>Sugar cane residues</td>
<td>7.019</td>
<td></td>
<td></td>
<td></td>
<td>1,1</td>
</tr>
<tr>
<td>Africa</td>
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<td>7.024</td>
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<td>Forest industry residues</td>
<td>7.038</td>
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</tr>
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<td>Cereal Straw/Husks</td>
<td>7.368</td>
<td></td>
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<td>Asia excl. China</td>
<td>Forest residues</td>
<td>7.409</td>
<td></td>
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</tr>
</tbody>
</table>

- **Positive > 2.5**
- **Neutral = 1.5 - 2.5**
- **Negative < 1.5**
GLOBAL BIOFUEL POTENTIALS FOR MARINE ENGINES

ANNEX
LITERATURE AND DATA – METHODOLOGY

Selected sources

- FAOSTAT (2012): FAO Statistical Database; online available: http://faostat.org
- Pöyry Database
- International Timber Trade Organization
- National statistics
- Various sources for conversion factors on, water content, heating values, straw grain ratios, residue yields for forestry, industry
LITERATURE AND DATA – COUNTRY RANKING
