Implications of biofuels policy mandate in Thailand on water

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### Biofuels Development Plan 2008 – 2022 in Thailand

#### Ethanol demand (M.litres/day)

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</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>1.24</td>
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<td>2.11</td>
<td>3.0</td>
<td>6.2</td>
<td>9.0</td>
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#### Biodiesel demand (M.litres/day)

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</thead>
<tbody>
<tr>
<td>Demand</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>3.0</td>
<td>3.6</td>
<td>5.97</td>
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<td>25.0</td>
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<td>25.0</td>
<td>25.0</td>
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</tr>
</tbody>
</table>

### Alternative Energy Development Plan: AEDP (2012-2021)

- **New alternative diesel**
  - Biodiesel from Jatropha, algae
  - ED95, FAEE, Diesohol
  - BHD, BTL

### Major feedstocks used for biofuels production

- **Bio-ethanol**
- **Biodiesel**
- Molasses
- Cassava
- Sugarcane
- Oil palm

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*Start E20*  
*Start E85 + Flex-fuel vehicle (FFV)*  
*Sell B3 nationwide and sell B5 as optional*
LCA perspective: impact on freshwater resources

Water deprivation from feedstock expansion in Thailand

Water requirement for biofuel feedstock cultivation

- Crop water requirement (CWR)
- $ET_c = K_c \times ET_0$
- Effective rainfall

Potential impact on water use

- Water stress index (WSI)
  $WSI = \frac{1}{1 + e^{-6.4(WTA) - \frac{1}{0.01} - 1}}$

- Water deprivation

Water deprivation ($m^3 H_2O_{eq} \text{ unit}^{-1}$) = Water deficit ($m^3 \text{ unit}^{-1}$) $\times$ WSI

Allen, 1998; RID, 2011; Pfister et al., 2009; Ridoutt B. and Pfister S., 2010; Gheewala et al. (2013)
Gheewala et al. (2014), Water 6(6): 1698-1718
WATER DEPRIVATION FROM FEEDSTOCK EXPANSION FOR BIOETHANOL
LCA perspective: impact on freshwater resources

Water deprivation from feedstock expansion in Thailand: Bioethanol

Objective
• Apply the WF and WSI approaches to help policy makers to understand the impacts of bioethanol production on water use and stress;

Scope of the assessment
• Feedstock: cassava, sugarcane and molasses.
• 48 registered bioethanol plants located nationwide area evaluated;
• Relevant to 26 provinces and 13 watersheds;
• Impact is evaluated by the characterization factor so called “water deprivation potential”

Gheewala et al. (2013), Bioresource Technology 150: 457–465
Bioethanol production systems in Thailand

Stage 1: Bioethanol crops cultivation
- Sugarcane cultivation
- Cassava cultivation

Sugarcane

Stage 2: Feedstock processing
- Sugar milling
  - Sugarcane juice
    - Sugar
      - Molasses
    - Bagasse
    - Residues
    - Effluents

Dried chip processing
- Fresh root cassava
- Dried chip cassava

Stage 3: Ethanol conversion
- Molasses ethanol conversion
  - Molasses ethanol
    - Residues
    - Effluents
- Sugarcane ethanol conversion
  - Sugarcane ethanol
    - Residues
    - Effluents
- Cassava ethanol conversion
  - Cassava ethanol
    - Residues
    - Effluents

Gheewala et al. (2013), Bioresource Technology 150: 457–465
Water Footprint of Bioethanol production

Comparative WF of the bioethanol feedstocks

Feedstock cultivation contributes around 97-98% of total blue water footprint of bioethanol

Comparative WF of bioethanol

<table>
<thead>
<tr>
<th>Bioethanol products</th>
<th>WF (L water/L bioethanol)</th>
<th>Total WF</th>
<th>Blue WF (Avg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava ethanol</td>
<td></td>
<td>2,372 – 2,579</td>
<td>528</td>
</tr>
<tr>
<td>Sugarcane ethanol</td>
<td></td>
<td>1,396 – 2,196</td>
<td>490</td>
</tr>
<tr>
<td>Molasses ethanol</td>
<td></td>
<td>1,976 – 3,105</td>
<td>699</td>
</tr>
</tbody>
</table>

Gheewala et al. (2013), Bioresource Technology 150: 457–465
### Implications of the bioethanol policy mandate on water use and stress

- **Scenario 1:** Policy mandate scenario
- **Scenario 2:** Full production capacity scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Water requirements (Million m$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry season</td>
</tr>
<tr>
<td></td>
<td>Green water</td>
</tr>
<tr>
<td>Cassava ethanol plants</td>
<td>754</td>
</tr>
<tr>
<td>Sugarcane ethanol plants</td>
<td>8</td>
</tr>
<tr>
<td>Molasses ethanol plants</td>
<td>102</td>
</tr>
<tr>
<td>Multi-feedstocks plants</td>
<td>74</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>938</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Water requirements (Million m$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry season</td>
</tr>
<tr>
<td></td>
<td>Green water</td>
</tr>
<tr>
<td>Cassava ethanol plants</td>
<td>1,047</td>
</tr>
<tr>
<td>Sugarcane ethanol plants</td>
<td>11</td>
</tr>
<tr>
<td>Molasses ethanol plants</td>
<td>141</td>
</tr>
<tr>
<td>Multi-feedstocks plants</td>
<td>103</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,303</strong></td>
</tr>
</tbody>
</table>

Gheewala et al. (2013), Bioresource Technology 150: 457–465
Implications of the bioethanol policy mandate on water use and stress

Share of water deprivation potentials from bioethanol production in 2021 classified by watersheds

Share of blue water requirements for bioethanol production in 2021 classified by watersheds

Gheewala et al. (2013), Bioresource Technology 150: 457–465
Recommendations to enhance water efficiency of bioethanol production in Thailand

- **Crop evapotranspiration (ET) reduction**
  - Development of crop varieties (drought-tolerant, high-yield, short growth period), improvement of agricultural practices using GAP in farming,

- **Promotion of sugarcane ethanol** (as nowadays there is only one ethanol plant using sugarcane juice in operation)

- **Enhancing water use efficiency in feedstock processing and ethanol conversion (water reuse and recycling program)**
  - New technologies development such as dry cleaning of sugar cane to eliminate sugarcane washing, treatment of vinasse by biodigestion technique to reduce the organic load and recirculating into the process

- **Promotion of bioethanol feedstock cultivation in the low water stress areas**

Gheewala et al. (2013), Bioresource Technology 150: 457–465
WATER DEPRIVATION FROM FEEDSTOCK EXPANSION FOR BIODIESEL
LCA perspective: impact on freshwater resources

Water deprivation from feedstock expansion in Thailand: Biodiesel

Objective

• Apply the WF and WSI approaches to help policy makers to understand the impacts of biodiesel production on water use and stress;

Scope of the assessment

• Feedstock: oil palm

• The suitable areas by the MOAC: 3 regions falling under 13 watersheds;

• Two boundaries: administrative and hydrological;

• Impact is evaluated by the characterization factor so called “water deprivation potential”
Biodiesel production systems in Thailand

Seed, Fertilizer, Herbicides, Diesel → Oil palm plantation → FFB → Diesel, Electricity

Palm oil milling

Kernel → PKO & PKE → CPO
Shell → Sold as biomass fuel
Fibre → Steam & Power production → Fly ash
POME → Open ponds → CH₄
EFB → Dumping
Decanter cake → Dumping

Cultivation: approximately 13,000 m³/ha/year (138 oil palm trees/ha)

- Feedstock cultivation contributes more than 99% of total freshwater for producing biodiesel

- The highest water demand: Central region

- The lowest water productivity: Southern region

- Water use efficiency is significantly affected by crop productivity for oil palm aged between 5 to 10 years
Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

• To mitigate the potential impact on freshwater resources, the suitable areas (by MOAC) located in Mun, Chao Phraya, West Coast Gulf are excluded.

• New oil palm plantation can either be expanded in a single region (Scenario 1) or spread over the three regions (Scenario 2).
  
  – Scenario 1: the expansion takes place in Eastern, Central, or Southern areas.
  
  – Scenario 2: the expansion is distributed proportionally, 79% in the South, 18% in the East and 3% in the Central region.
Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

The total additional freshwater withdrawal of oil palm expansion in the Eastern and Central regions of Scenario 1 is higher than that of Scenario 2.

### Scenario 1

<table>
<thead>
<tr>
<th>Year</th>
<th>South (100% plantation)</th>
<th>East (100% plantation)</th>
<th>Central (100% plantation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainwater</td>
<td>Blue water</td>
<td>Rainwater</td>
</tr>
<tr>
<td>2013</td>
<td>465.8</td>
<td>104.6</td>
<td>383.6</td>
</tr>
<tr>
<td>2014</td>
<td>684.2</td>
<td>153.6</td>
<td>563.6</td>
</tr>
<tr>
<td>2015</td>
<td>842.5</td>
<td>189.1</td>
<td>693.9</td>
</tr>
<tr>
<td>2016</td>
<td>959.6</td>
<td>215.4</td>
<td>790.4</td>
</tr>
<tr>
<td>2017</td>
<td>1,035.6</td>
<td>232.5</td>
<td>853.0</td>
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<tr>
<td>2018</td>
<td>1,122.8</td>
<td>264.2</td>
<td>927.0</td>
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<tr>
<td>2019</td>
<td>1,192.0</td>
<td>285.4</td>
<td>985.0</td>
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<tr>
<td>2020</td>
<td>1,252.8</td>
<td>303.2</td>
<td>1,035.8</td>
</tr>
<tr>
<td>2021</td>
<td>1,310.7</td>
<td>319.2</td>
<td>1,084.0</td>
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<td></td>
<td>8,866</td>
<td>2,067</td>
<td>7,316</td>
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<tr>
<td>Total</td>
<td></td>
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</table>

Rainwater: 8,866
Blue water: 2,067
Total: 10,933

### Scenario 2

<table>
<thead>
<tr>
<th>Year</th>
<th>South (79% plantation)</th>
<th>East (18% plantation)</th>
<th>Central (3% plantation)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainwater</td>
<td>Blue water</td>
<td>Rainwater</td>
<td>Blue water</td>
</tr>
<tr>
<td>2013</td>
<td>366.2</td>
<td>82.2</td>
<td>70.4</td>
<td>37.8</td>
</tr>
<tr>
<td>2014</td>
<td>537.9</td>
<td>120.8</td>
<td>103.4</td>
<td>55.6</td>
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<tr>
<td>2015</td>
<td>662.4</td>
<td>148.7</td>
<td>127.3</td>
<td>68.4</td>
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<td>2016</td>
<td>754.4</td>
<td>169.4</td>
<td>145.0</td>
<td>78.0</td>
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<td>2017</td>
<td>814.2</td>
<td>182.8</td>
<td>156.5</td>
<td>84.1</td>
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<td>2018</td>
<td>882.7</td>
<td>207.7</td>
<td>170.1</td>
<td>93.1</td>
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<td>2019</td>
<td>937.1</td>
<td>224.4</td>
<td>180.7</td>
<td>99.6</td>
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<tr>
<td>2020</td>
<td>985.0</td>
<td>238.4</td>
<td>190.0</td>
<td>105.2</td>
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<td>198.9</td>
<td>110.4</td>
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<tr>
<td>Rainwater</td>
<td>6,970</td>
<td>1,342</td>
<td>196</td>
<td>8,508</td>
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<tr>
<td>Water deficit</td>
<td>1,625</td>
<td>732</td>
<td>153</td>
<td>2,511</td>
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<tr>
<td>Total</td>
<td></td>
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## Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

<table>
<thead>
<tr>
<th>Year</th>
<th>Scenario 1 Water deprivation (million m$^3$H$<em>2$O$</em>{eq}$)</th>
<th>Scenario 2 Water deprivation (million m$^3$H$<em>2$O$</em>{eq}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South (100%)</td>
<td>East (100%)</td>
</tr>
<tr>
<td>2013</td>
<td>4.5</td>
<td>3.9</td>
</tr>
<tr>
<td>2014</td>
<td>6.6</td>
<td>5.8</td>
</tr>
<tr>
<td>2015</td>
<td>8.1</td>
<td>7.1</td>
</tr>
<tr>
<td>2016</td>
<td>9.3</td>
<td>8.1</td>
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<tr>
<td>2017</td>
<td>10.0</td>
<td>8.7</td>
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<td>2018</td>
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<td>12.3</td>
<td>10.3</td>
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<tr>
<td>2020</td>
<td>13.0</td>
<td>10.9</td>
</tr>
<tr>
<td>2021</td>
<td>13.7</td>
<td>11.4</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>88.9</strong></td>
<td><strong>75.8</strong></td>
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### Proportional areas

<table>
<thead>
<tr>
<th>Cases</th>
<th>Proportional areas</th>
<th>Water deficit (million m$^3$)</th>
<th>Water deprivation (million m$^3$H$<em>2$O$</em>{eq}$ ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18%</td>
<td>79%</td>
<td>3%</td>
</tr>
<tr>
<td>2</td>
<td>8%</td>
<td>90%</td>
<td>2%</td>
</tr>
<tr>
<td>3</td>
<td>4%</td>
<td>95%</td>
<td>1%</td>
</tr>
<tr>
<td>4</td>
<td>0.5%</td>
<td>99%</td>
<td>0.5%</td>
</tr>
<tr>
<td>5</td>
<td>0.09%</td>
<td>99.9%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
Recommendations to enhance water efficiency of biodiesel production in Thailand

- The efficiency of water used in plantation depends on how well farmers meet the GAP standard to retain the peak crop productivity during that age.
- Development of oil palm varieties, with high oil yields, tolerance of drought, can help to reduce water used by the crop.
- The areas for oil palm cultivation are recommended based on low potential of water stress and small amount of additional freshwater withdrawal.
  - Central region potentially faces more water stress than cultivating oil palm in other regions.
  - The most advantageous option is expansion in the Eastern region (East Coast Gulf and Trat province).
Summary of results – biofuels

• Feedstock cultivation is the most water intensive process for producing biofuels.

• Agricultural practices and development of crop varieties significantly influence to reduce water used in the cultivation process.

• Water deprivation can help to indicate areas having potential for inducing water stress in watershed leading to people in these areas being less vulnerable to water stress.

• Additional freshwater withdrawal will lead to higher water deprivation especially in watersheds having extreme and moderate water stress.
THANK YOU

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