PRISM™
REFINING AND MARKETING
INDUSTRY ANALYSIS SYSTEM

PRODUCT DESCRIPTION

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INTRODUCTION

Baker & O'Brien, Inc.’s PRISM™ modeling system is a powerful tool for analysis of refineries and the refining and marketing supply chain. Initially conceived and developed over 20 years ago, the PRISM system has been updated and expanded into one of the most flexible and comprehensive refining industry analysis tools available on the market today. The PRISM system combines a large historical technical/economic database (the “Database”) with a robust refinery simulator (the “Simulator”) and several crude assay and crude blending tools. The Database includes extensive information on:

- Refinery processing capacities;
- Refinery configurations and process technologies;
- Crude and intermediate feedstock runs;
- Product slates and qualities;
- Product distribution and sales patterns;
- Operating costs;
- Crude and product logistics;
- Carbon dioxide emissions;
- Transportation costs; and
- Financial performance.

The PRISM software is offered on a license-only basis. Licensees have the option of subscribing to any or all of the four PRISM Data Services that cover a total of 271 operational refineries: \(^1\) the United States Data Service (USDS), the Canadian Data Service (CANDS), the European Data Service (EDS), and the Asia-Pacific Data Service (APDS). The USDS includes information for essentially all operating petroleum refineries in the United States (U.S.). The USDS is updated quarterly, and historical data is available back to 2010. CANDS, EDS, and APDS are updated annually. CANDS includes all Canadian refineries, and data are available beginning with

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\(^1\) Operational as of January 1, 2018.
calendar year 2011. The EDS includes Europe west of Russia, plus Turkey, Israel, and Saudi Arabia. It begins with data for 2012 and includes the 92 refineries listed in Appendix A. Refineries in the EDS represent 90% of regional refining capacity. The APDS covers 77 refineries beginning with 2011 data (see Appendix B). Licensees are also able to build their own models of refineries not included in our subscription services.

No confidential data is solicited from PRISM Data Service subscribers. The Data Services are based on publicly-available data, filtered and enhanced with the experience and judgment of Baker & O’Brien’s consulting staff. As a result, the Data Services provide detailed information on individual refineries.

Calculations are performed using the PRISM Simulator (part of the software provided to PRISM licensees). The PRISM Simulator employs a non-linear, deterministic approach, although several linear programming (LP) sub-routines are used for refinery product blending optimization. The Simulator strikes a balance between technical sophistication and ease-of-use.

PRISM subscribers are able to review, supplement, and/or revise the data provided for individual refineries and, using the PRISM Simulator, make their own analyses. PRISM licensees use the model for a wide variety of purposes. It has proven to be especially useful and valuable in the following areas:

- Crude oil marketing and trading;
- Screening of potential refinery acquisitions;
- Competitive benchmarking;
- Evaluating the impact of new environmental regulations;
- Evaluating carbon dioxide (CO2) emissions;
- Screening new feedstocks;
- Screening new configurations for existing or grassroots refineries;
- Evaluating bitumen upgrading schemes;
- Refinery hydrogen balance analysis;

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2 84 of the 92 refineries were operating in 2017.
3 APDS includes 19 North American and 2 South American refineries. 71 of the 77 refineries were operating in 2017.
• Analysis of capital investments;

• Benchmarking of refining costs and margins;

• Operations analysis;

• Regional analysis of product markets;

• Crude and product pipeline capacity utilization studies;

• Wholesale market strategy rationalization; and

• Product netback analysis.

Current PRISM software licensees include integrated international oil companies, independent refiners, crude and synthetic crude oil producers, crude and product traders, industrial gas producers, pipeline companies, and refinery technology licensors. Thirteen refining companies license the PRISM system, including eight of the top ten largest North American refining companies. There are PRISM users in Asia, Europe, North and South America.
REFINING INDUSTRY STUDIES

The PRISM U.S. Data Service includes detailed estimates of individual refinery operations and financial performance. Because the data are derived from public sources, individual refineries can be named. The data includes unit capacities, configurations, operating parameters, refinery crude slates, feedstock purchases, yields, and product distribution. Variable expenses such as fuel, electricity, steam, and hydrogen, and fixed costs including employee head counts are estimated. Turnaround activity, unplanned unit outages, shutdowns, and new construction are monitored to keep the PRISM Database current. Starting in 2018, refinery operating data provided by Genscape International, Inc. is used in the analysis.

FIGURE 1
MULTI-REFINERY FINANCIAL REPORT

FINANCIAL RESULTS
US : Qtr 20

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Total Input MBPCD</th>
<th>Crude °API</th>
<th>Crude Sulfur wt. %</th>
<th>Complex Factor</th>
<th>US Dollars Per Barrel of Input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gross Margin</td>
</tr>
<tr>
<td>Refinery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.57</td>
</tr>
<tr>
<td>Wilmington, CA</td>
<td>0.0</td>
<td>22.37</td>
<td>2.91%</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>Refinery</td>
<td></td>
<td>24.32</td>
<td>2.41%</td>
<td>17.7</td>
<td>12.53</td>
</tr>
<tr>
<td>Wilmington, CA</td>
<td>0.7</td>
<td>19.51</td>
<td>3.98%</td>
<td>15.7</td>
<td></td>
</tr>
<tr>
<td>Refinery</td>
<td></td>
<td>29.10</td>
<td>0.88%</td>
<td>18.3</td>
<td>12.68</td>
</tr>
<tr>
<td>Wilmington, CA</td>
<td>0.9</td>
<td>25.58</td>
<td>1.21%</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Refinery</td>
<td></td>
<td>10.92</td>
<td>5.18</td>
<td>5.74</td>
<td>3.38</td>
</tr>
<tr>
<td>Martinez, CA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.92</td>
</tr>
</tbody>
</table>

Note: Company names are displayed in the actual PRISM report.

PRISM licensees use the database to measure the performance of individual refineries against any grouping of competitors. PRISM data are current so performance can be tracked on an on-going basis. Users can analyze financial and operational trends and perform screening studies to support merger and acquisition activities.
Since the PRISM Database is kept up-to-date, it provides an ideal starting point for investment studies, analysis of changing fuel specifications, and market demand patterns. Licensees have used the PRISM system to analyze the regional impact of regulatory changes in product specification (i.e., diesel sulfur and gasoline benzene levels), green-house gas regulations, and the survivability of individual refineries. Figure 3 is from a report that Baker & O’Brien performed on behalf of a major industry association. Using the PRISM system, we measured the costs of pending gasoline rules on a refinery-by-refinery basis and generated the supply curve shown below.
CARBON DIOXIDE EMISSIONS

The imposition of CO₂ emissions limits and credit trading schemes has added a new dimension to refinery economic analysis. The PRISM Refinery Simulator calculates CO₂ emissions based on crude slates, throughput, and other operational factors. Refiners and traders can:

- Compare the emissions of individual refineries;
- Evaluate the impact of changes in crude slate or other operating changes on emissions; and
- Calculate the value of CO₂ credits to individual refineries.

FIGURE 4
CO₂ EMISSIONS FROM SELECTED CANADIAN REFINERIES

<table>
<thead>
<tr>
<th>Operations Summary – Canada</th>
<th>Company A Alberta Canada</th>
<th>Company B Maritimes Canada</th>
<th>Company C Ontario Canada</th>
<th>Company D Maritimes Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 Tonne/yr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ EMISSIONS</td>
<td>1,975</td>
<td>598</td>
<td>1,239</td>
<td>4,149</td>
</tr>
<tr>
<td>CO₂ from Fluid Catalytic Cracking</td>
<td>1,039</td>
<td>276</td>
<td>371</td>
<td>1,458</td>
</tr>
<tr>
<td>CO₂ from Steam Methane Reforming</td>
<td>447</td>
<td>237</td>
<td>228</td>
<td>601</td>
</tr>
<tr>
<td>CO₂ from Plant Fuel Gas Consumed</td>
<td>278</td>
<td>458</td>
<td>1,398</td>
<td></td>
</tr>
<tr>
<td>CO₂ from Liquid Fuel Consumed</td>
<td>211</td>
<td>85</td>
<td>181</td>
<td>399</td>
</tr>
<tr>
<td>CO₂ from Purchased Fuel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ Associated w/Purchased Electricity</td>
<td>211</td>
<td>85</td>
<td>181</td>
<td>399</td>
</tr>
</tbody>
</table>
CRUDE OIL ECONOMICS AND MARKETING

The PRISM system is an excellent tool for evaluating crude oil substitution economics. Support of crude oil marketing and trading groups is one of its major uses. Because the PRISM Databases include capacity, configuration, and current crude slate data, it is ideal for selecting target refineries for crude marketing campaigns. It is easy to calculate crude economics and evaluate combined capital investment and crude slate changes (i.e., the addition of a coker or hydrocracker combined with a shift to heavier, more-sour crude oils).
### FIGURE 5

**VALUE OF URALS IN A NORTHWESTERN EUROPEAN REFINERY**

<table>
<thead>
<tr>
<th>Crude</th>
<th>Base</th>
<th>Alternate</th>
<th>Change</th>
<th>PRICE US $</th>
<th>Cash US $000/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baerath Light 33.0</td>
<td>25,316</td>
<td>25,316</td>
<td>0</td>
<td>87.94</td>
<td>455</td>
</tr>
<tr>
<td>Es Sider 36.3</td>
<td>3,824</td>
<td>3,824</td>
<td>0</td>
<td>92.17</td>
<td>119</td>
</tr>
<tr>
<td>NKossa Swt 41.3</td>
<td>5,666</td>
<td>5,666</td>
<td>0</td>
<td>87.35</td>
<td>(260)</td>
</tr>
<tr>
<td>Oseberg 35.9</td>
<td>12,440</td>
<td>12,440</td>
<td>0</td>
<td>90.90</td>
<td>109</td>
</tr>
<tr>
<td>Sirri 33.4</td>
<td>60,670</td>
<td>60,670</td>
<td>0</td>
<td>91.78</td>
<td>8</td>
</tr>
<tr>
<td>Urals 31.8</td>
<td>183,638</td>
<td>203,638</td>
<td>20,000</td>
<td>666.47</td>
<td>179</td>
</tr>
<tr>
<td>TOTAL CRUDE</td>
<td>291,554</td>
<td>311,554</td>
<td>20,000</td>
<td>31.05</td>
<td>621</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Feedstocks</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen (FOE)</td>
<td>4,234</td>
<td>4,581</td>
<td>347</td>
<td>107.15</td>
<td>37</td>
</tr>
<tr>
<td>Ethanol</td>
<td>2,107</td>
<td>2,107</td>
<td>0</td>
<td>91.69</td>
<td>0</td>
</tr>
<tr>
<td>Isobutane</td>
<td>1,895</td>
<td>1,644</td>
<td>(251)</td>
<td>59.14</td>
<td>(15)</td>
</tr>
<tr>
<td>BioDiesel</td>
<td>4,077</td>
<td>4,081</td>
<td>4</td>
<td>144.86</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL OTHER FEEDSTOCKS</td>
<td>12,313</td>
<td>12,413</td>
<td>100</td>
<td>1.15</td>
<td>23</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Light Oil Products</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EURO 10ppm 95 RON</td>
<td>33,554</td>
<td>38,728</td>
<td>5,175</td>
<td>87.94</td>
<td>455</td>
</tr>
<tr>
<td>EURO 10ppm 98 RON</td>
<td>8,388</td>
<td>9,682</td>
<td>1,294</td>
<td>92.17</td>
<td>119</td>
</tr>
<tr>
<td>EURO 10ppm E5 BOB 95 RON</td>
<td>11,859</td>
<td>8,893</td>
<td>(2,975)</td>
<td>87.35</td>
<td>(260)</td>
</tr>
<tr>
<td>US RBOB E10 Reg</td>
<td>2,965</td>
<td>2,221</td>
<td>(744)</td>
<td>93.56</td>
<td>(70)</td>
</tr>
<tr>
<td>Jet A-1</td>
<td>17,493</td>
<td>18,693</td>
<td>1,200</td>
<td>90.90</td>
<td>109</td>
</tr>
<tr>
<td>EURO Diesel 10 ppm</td>
<td>79,095</td>
<td>79,177</td>
<td>82</td>
<td>91.78</td>
<td>8</td>
</tr>
<tr>
<td>EURO L Heating Oil 1000 ppm</td>
<td>33,529</td>
<td>35,829</td>
<td>2,300</td>
<td>666.47</td>
<td>179</td>
</tr>
<tr>
<td>TOTAL LIGHT OIL PRODUCTS</td>
<td>205,703</td>
<td>212,946</td>
<td>7,243</td>
<td>31.05</td>
<td>621</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Products</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>6,687</td>
<td>7,215</td>
<td>528</td>
<td>51.83</td>
<td>27</td>
</tr>
<tr>
<td>Normal Butane</td>
<td>5,735</td>
<td>6,121</td>
<td>386</td>
<td>57.68</td>
<td>22</td>
</tr>
<tr>
<td>Mixed BB</td>
<td>3,801</td>
<td>5,079</td>
<td>1,278</td>
<td>79.75</td>
<td>102</td>
</tr>
<tr>
<td>Propylene-Refinery Grade</td>
<td>7,952</td>
<td>8,508</td>
<td>556</td>
<td>103.53</td>
<td>58</td>
</tr>
<tr>
<td>Benzene</td>
<td>365</td>
<td>382</td>
<td>17</td>
<td>133.26</td>
<td>2</td>
</tr>
<tr>
<td>Toluene</td>
<td>3,832</td>
<td>3,997</td>
<td>165</td>
<td>113.00</td>
<td>19</td>
</tr>
<tr>
<td>Mixed Xylenes</td>
<td>6,308</td>
<td>6,577</td>
<td>269</td>
<td>115.52</td>
<td>31</td>
</tr>
<tr>
<td>Light Naphtha</td>
<td>20,874</td>
<td>21,197</td>
<td>323</td>
<td>89.62</td>
<td>29</td>
</tr>
<tr>
<td>Heavy Naphtha</td>
<td>1,310</td>
<td>1,310</td>
<td>0</td>
<td>78.61</td>
<td>103</td>
</tr>
<tr>
<td>Aromatic Raffinate</td>
<td>7,454</td>
<td>7,798</td>
<td>344</td>
<td>84.90</td>
<td>29</td>
</tr>
<tr>
<td>Sour VGO (&gt;75% S)</td>
<td>7,931</td>
<td>7,931</td>
<td>0</td>
<td>78.25</td>
<td>621</td>
</tr>
<tr>
<td>Resid Fuel Oil-S Varies</td>
<td>36,690</td>
<td>36,242</td>
<td>(448)</td>
<td>450.10</td>
<td>(32)</td>
</tr>
<tr>
<td>Sulfur (FOE)</td>
<td>590</td>
<td>624</td>
<td>34</td>
<td>120.90</td>
<td>3</td>
</tr>
<tr>
<td>Produced Fuel Gas (FOE)</td>
<td>7,220</td>
<td>9,471</td>
<td>2,251</td>
<td>45.80</td>
<td>103</td>
</tr>
<tr>
<td>TOTAL OTHER PRODUCTS</td>
<td>107,509</td>
<td>122,455</td>
<td>14,945</td>
<td>55.86</td>
<td>1,117</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utilities</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel-Produced (MMBTU)</td>
<td>45,485</td>
<td>49,018</td>
<td>3,533</td>
<td>7.27</td>
<td>26</td>
</tr>
<tr>
<td>Fuel-Purchased (MMBTU)</td>
<td>71,185</td>
<td>75,726</td>
<td>4,542</td>
<td>7.27</td>
<td>33</td>
</tr>
<tr>
<td>Electric Power (MW-h)</td>
<td>5,5</td>
<td>5</td>
<td>95.92</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cooling Water Make-up (kcal)</td>
<td>4,635</td>
<td>4,878</td>
<td>242</td>
<td>0.20</td>
<td>0</td>
</tr>
<tr>
<td>Process Water (kcal)</td>
<td>464</td>
<td>488</td>
<td>24</td>
<td>0.50</td>
<td>0</td>
</tr>
<tr>
<td>Boiler Feed Water (kcal)</td>
<td>1,941</td>
<td>2,067</td>
<td>126</td>
<td>2.50 kcal</td>
<td>0</td>
</tr>
<tr>
<td>Catalyst and Chemicals (US $)</td>
<td>81,915</td>
<td>87,976</td>
<td>6,061</td>
<td>1.00 US $</td>
<td>6</td>
</tr>
<tr>
<td>CO2 Emissions (Tonne)</td>
<td>10,247</td>
<td>11,053</td>
<td>806</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL UTILITIES</td>
<td>3.28</td>
<td>4.28</td>
<td>1,000</td>
<td>66</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRUDE VALUE</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>82.47</td>
<td>/B-Urals</td>
<td>1,649</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The *PRISM* software package includes a Crude Assay Library containing over 340 assays as shown in Appendix C. As part of the Data Services, new crude assays continue to be added to the library. Licensees can add assays to their proprietary copy of the *PRISM* Crude Assay Library with the easy-to-use *PRISM* Crude Assay Director.
The PRISM Crude Assay Blend Optimizer uses an LP solver to blend crude to meet user defined crude properties. It is primarily used by crude oil traders to determine the most profitable mix of component crudes that will meet industry specifications for crude blends such as Louisiana Light Sweet (LLS) or West Texas Intermediate (WTI).

The PRISM industry model includes not only the refineries but also the crude transportation system. Pipeline and tanker routes are modeled, and utilization rates and logistical constraints can be analyzed. Figure 6 illustrates pipeline flow detail.

**FIGURE 6**

**CRUDE PIPELINE TRANSPORTATION DETAIL**
PRODUCT SUPPLY AND MARKETING ANALYSIS

The PRISM industry model includes the distribution system extending from refineries to and including unbranded wholesale terminals or spot markets. The PRISM U.S. Data Service includes approximately 85 product markets. The distribution model includes current and historical transportation routes and costs. Most of the published common carrier product pipeline tariffs are included in the Database. **Figure 7** illustrates the detail provided.

**FIGURE 7**
PRODUCT TRANSPORTATION DETAIL

The PRISM Database has the ability to track pipeline capacity. Pipeline throughputs are calculated, and the PRISM system can be used to analyze distribution system utilization and constraints.
PRISM calculates the delivered cost of products to each of the terminals in the PRISM model. This allows users to analyze marketing economics and evaluate product exchange opportunities. Figure 8 shows the delivered cost of product to Los Angeles and the estimated volumes supplied by individual refineries.

**FIGURE 8**

**COST OF GASOLINE DELIVERED TO NEW YORK**

<table>
<thead>
<tr>
<th>Delivered Cost - NY-NY Spot</th>
<th>2012 Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>US RBOB E10 Reg</td>
<td>Cost at Source</td>
</tr>
<tr>
<td>GBR-Humberside: Phillips 66</td>
<td>xxx</td>
</tr>
<tr>
<td>GBR-Stanlow: Essar</td>
<td>xxx</td>
</tr>
<tr>
<td>PRT-Sines: GALP</td>
<td>xxx</td>
</tr>
<tr>
<td>NLD-Pernis: Shell</td>
<td>xxx</td>
</tr>
<tr>
<td>FIN-Porvoo: Neste</td>
<td>xxx</td>
</tr>
<tr>
<td>BEL-AN-Antwerp: Total</td>
<td>xxx</td>
</tr>
<tr>
<td>ITA-Sarroch: Saras</td>
<td>xxx</td>
</tr>
<tr>
<td>NLD-Vlissingen: Zeeland</td>
<td>xxx</td>
</tr>
<tr>
<td>NLD-Europoort: BP</td>
<td>xxx</td>
</tr>
<tr>
<td>ESP-Castellon de la Plana: BP</td>
<td>xxx</td>
</tr>
<tr>
<td>FRA-Grandpuits: Total</td>
<td>xxx</td>
</tr>
<tr>
<td>ITA-Gela: Eni</td>
<td>xxx</td>
</tr>
<tr>
<td>NLD-Rotterdam: ExxonMobil</td>
<td>xxx</td>
</tr>
<tr>
<td>NOR-Slagen: ExxonMobil</td>
<td>xxx</td>
</tr>
<tr>
<td>ITA-Milazzo: Raff di Milazzo</td>
<td>xxx</td>
</tr>
<tr>
<td>BEL-AN-Antwerp: ExxonMobil</td>
<td>xxx</td>
</tr>
<tr>
<td>ITA-Priolo-Melilli: ISAB</td>
<td>xxx</td>
</tr>
</tbody>
</table>

Quantities and costs are displayed in the actual PRISM report.

PRISM is also used to evaluate the product supply implications of process unit shutdowns and refinery interruptions. Beginning with Baker & O’Brien’s most recent production estimate, it is easy to simulate the effect of a shutdown of a coker, FCC, or other major unit on the availability of products from any refinery.
**TECHNICAL DESCRIPTION**

The relationship of the core PRISM system components is illustrated in Figure 9 (The Crude Assay Viewer and Crude Assay Blend Optimizer are not shown). Each of the components is described in more detail in the following sections.

**FIGURE 9**

*PRISM SYSTEM COMPONENT RELATIONSHIPS*

- Refinery Simulator (Microsoft Excel)
  - Open Microsoft Excel Based Simulator
  - One of “Every” Type of Unit
  - Non-linear Unit Models
  - LP Blending of Gasoline and Distillates
  - Automated Data Transfer to/from Access Database

- User Interface (Menu System)

- Crude Assay Director (Microsoft Excel)
  - Data entry system for PRISM assay library
  - Use Properties from Similar Crudes to Supplement Available Data
  - Curve-fit Property Data and Generate Coefficients

- Data Files (Microsoft Access)

**PRISM DATA MODULES**

The PRISM Industry Model includes crude oil at the load port or initial pipeline injection point, refineries, unbranded wholesale terminals, and the transportation systems that connects them. Baker & O’Brien is continuously collecting information on the refining and marketing industry including:

- Refinery configuration;
- Construction and turnaround plans and costs;
- Refinery and marketing operating costs;
• Crude pricing, supply and logistics;
• Crude and product transportation costs;
• Product distribution logistics and costs; and
• Product pricing for both spot and rack markets.

Sources include a wide variety of industry publications, government agency reports, and published company information, filtered with the expertise and judgment of Baker & O’Brien consultants. On a quarterly (U.S.) or annual (other regions) basis, this information is processed using the PRISM Simulator to generate estimates of refinery operations and profitability on an individual refinery basis. The data are published to PRISM Data Service subscribers in Microsoft® Access data files (PRISM Data Modules).

The Data Module structure is designed to allow users to collect and disseminate industrial intelligence within an organization. Baker & O’Brien's published Data Module contains quarterly (U.S.) or annual averages, but users may create daily, weekly, monthly, or any other time frame to meet their requirements. The PRISM software includes a utility for aggregating the quarterly data into annual averages or any other grouping. Users may supplement the published data, adding refineries, product terminals, crudes, or any other data required for special studies.

**USER INTERFACE**

The PRISM User Interface is a user-friendly, intuitive tool that guides the user to the data of interest or through the process of configuring and executing a Simulator run. Examples of the interface screens are shown in Figure 10 and Figure 11.
FIGURE 10

REFINERY MENU

There are 722 refineries in the PRISM database. As of 23-Aug-13:
26 are planned, but not yet operational.
58 are permanently closed.
67 are modeled (have capacity/configuration data) in the
2012 Europe data module. All 67 have been simulated.
Only the modeled refineries are shown in the list. Ownership is as of 23-Aug-13.

Use the check boxes to select multiple refineries.

FIGURE 11

PROCESS DETAILS

Jan-01 (company website): Two trains—a high TAN train that started up in 1996 has an
atmospheric towers and a vacuum tower. The other train has an atmospheric tower and two
vacuum towers that operate in series.
The User Interface module includes over a dozen predefined reports that can be accessed by the click of a button. Reports can be generated for individual refineries or any grouping of interest. An example report is shown below (Figure 12).
### FIGURE 12

**PRISM REFINERY MARGIN REPORT**

Northwest European Refinery

<table>
<thead>
<tr>
<th>Description</th>
<th>Liquid Sp. Gr</th>
<th>Quantity</th>
<th>PRICE</th>
<th>Cash</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arzew 45.0</td>
<td>0.8015</td>
<td>110</td>
<td>55.09</td>
<td>48</td>
</tr>
<tr>
<td>Bonny Light 35.1</td>
<td>0.8484</td>
<td>386</td>
<td>56.11</td>
<td>161</td>
</tr>
<tr>
<td>DUC 34.8</td>
<td>0.8507</td>
<td>827</td>
<td>55.91</td>
<td>342</td>
</tr>
<tr>
<td>Eagle Ford Condinst 59.8</td>
<td>0.7397</td>
<td>184</td>
<td>47.50</td>
<td>74</td>
</tr>
<tr>
<td>Forties 40.3 [2007]</td>
<td>0.8235</td>
<td>318</td>
<td>54.21</td>
<td>132</td>
</tr>
<tr>
<td>Gullfaks 27.5</td>
<td>0.8371</td>
<td>7,980</td>
<td>55.55</td>
<td>3,334</td>
</tr>
<tr>
<td>Sleipner Condensate 59.8</td>
<td>0.7395</td>
<td>2,291</td>
<td>48.50</td>
<td>946</td>
</tr>
<tr>
<td>Urals 31.8</td>
<td>0.8662</td>
<td>1,855</td>
<td>52.88</td>
<td>713</td>
</tr>
<tr>
<td><strong>TOTAL CRUDE</strong></td>
<td>13,951</td>
<td>106,852</td>
<td>53.81</td>
<td>5,750</td>
</tr>
<tr>
<td><strong>Other Feedstocks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Natural Gas</td>
<td>1</td>
<td>4</td>
<td>36.86</td>
<td>0</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>41</td>
<td>879</td>
<td>86.24</td>
<td>76</td>
</tr>
<tr>
<td>BioDiesel-FAME</td>
<td>0.8750</td>
<td>448</td>
<td>125.45</td>
<td>405</td>
</tr>
<tr>
<td>ETBE</td>
<td>0.7527</td>
<td>418</td>
<td>110.55</td>
<td>387</td>
</tr>
<tr>
<td>Alkyate</td>
<td>0.6960</td>
<td>553</td>
<td>66.96</td>
<td>335</td>
</tr>
<tr>
<td><strong>TOTAL OTHER FEEDSTOCKS</strong></td>
<td>1,461</td>
<td>12,610</td>
<td>95.36</td>
<td>1,202</td>
</tr>
<tr>
<td><strong>TOTAL INPUTS</strong></td>
<td>15,412</td>
<td>119,462</td>
<td>58.20</td>
<td>6,952</td>
</tr>
<tr>
<td><strong>Light Oil Products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EURO 10ppm 95 RON</td>
<td>0.7196</td>
<td>2,366</td>
<td>70.38</td>
<td>1,457</td>
</tr>
<tr>
<td>EURO 10ppm 98 RON</td>
<td>0.7523</td>
<td>314</td>
<td>79.17</td>
<td>208</td>
</tr>
<tr>
<td>EURO 10ppm E5 BOB 95 R</td>
<td>0.7576</td>
<td>1,964</td>
<td>69.26</td>
<td>1,100</td>
</tr>
<tr>
<td>EURO Diesel 10 ppm</td>
<td>0.8200</td>
<td>6,793</td>
<td>69.72</td>
<td>3,636</td>
</tr>
<tr>
<td>EURO LI Heating Oil 1000 pt</td>
<td>0.8277</td>
<td>281</td>
<td>491.40</td>
<td>138</td>
</tr>
<tr>
<td><strong>TOTAL LIGHT OIL PRODUCTS</strong></td>
<td>11,719</td>
<td>93,952</td>
<td>69.93</td>
<td>6,570</td>
</tr>
<tr>
<td><strong>Other Products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>0.5102</td>
<td>124</td>
<td>36.75</td>
<td>56</td>
</tr>
<tr>
<td>Isobutane</td>
<td>0.5634</td>
<td>106</td>
<td>40.32</td>
<td>48</td>
</tr>
<tr>
<td>Normal Butane</td>
<td>0.5841</td>
<td>179</td>
<td>40.78</td>
<td>79</td>
</tr>
<tr>
<td>LSR Naphtha</td>
<td>0.6836</td>
<td>391</td>
<td>62.83</td>
<td>226</td>
</tr>
<tr>
<td>Asphalt</td>
<td>0.9644</td>
<td>369</td>
<td>57.63</td>
<td>113</td>
</tr>
<tr>
<td>Resid Fuel Oil-S Varies</td>
<td>0.9950</td>
<td>2,088</td>
<td>297.67</td>
<td>622</td>
</tr>
<tr>
<td>Sulfur</td>
<td>20</td>
<td>28</td>
<td>126.98</td>
<td>3</td>
</tr>
<tr>
<td>Produced Fuel Gas</td>
<td>222</td>
<td>1,789</td>
<td>42.92</td>
<td>1,146</td>
</tr>
<tr>
<td>Produced Fuel Liquid</td>
<td>0.9950</td>
<td>232</td>
<td>42.92</td>
<td>1,146</td>
</tr>
<tr>
<td>Refinery Loss</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Vent Gases</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL OTHER PRODUCTS</strong></td>
<td>3,693</td>
<td>26,699</td>
<td>42.92</td>
<td>1,146</td>
</tr>
<tr>
<td><strong>TOTAL PRODUCTS</strong></td>
<td>15,412</td>
<td>120,651</td>
<td>63.95</td>
<td>7,716</td>
</tr>
<tr>
<td><strong>GAIN/(LOSS)</strong></td>
<td>0</td>
<td>1,189</td>
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<tr>
<td><strong>GROSS MARGIN</strong></td>
<td>6.39</td>
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<td></td>
<td>764</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel-Produced</td>
<td>20,500</td>
<td>0.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fuel-Purchased</td>
<td>25,459</td>
<td>5.85</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Electric Power</td>
<td>499</td>
<td>54.93</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Coding Water Make-up</td>
<td>1,599</td>
<td>0.20</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Process Water</td>
<td>160</td>
<td>0.50</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Boiler Feed Water</td>
<td>924</td>
<td>2.50</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Catalyst and Chemicals</td>
<td>16,559</td>
<td>1.00</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>CO2 Emissions</td>
<td>3,059</td>
<td>0.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SO2 Emissions</td>
<td>5</td>
<td>0.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL UTILITIES</strong></td>
<td>1.64</td>
<td></td>
<td>196</td>
<td></td>
</tr>
<tr>
<td><strong>VARIABLE MARGIN</strong></td>
<td>4.75</td>
<td></td>
<td>568</td>
<td></td>
</tr>
<tr>
<td><strong>Fixed Costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Labor</td>
<td>52,153</td>
<td>0.44</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Maintenance Labor</td>
<td>128,143</td>
<td>1.07</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Turnaround Accrual</td>
<td>64,071</td>
<td>0.54</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Maintenance Materials</td>
<td>64,071</td>
<td>0.54</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Operating Materials &amp; Supplies</td>
<td>8,213</td>
<td>0.07</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Waste Disp/Environmental</td>
<td>10,951</td>
<td>0.09</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Rentals &amp; Contract Services</td>
<td>8,213</td>
<td>0.07</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Ad Val Taxes, License, Royalty</td>
<td>24,231</td>
<td>0.20</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>35,414</td>
<td>0.30</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Mgmt, Profess. &amp; Staff</td>
<td>35,162</td>
<td>0.29</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Other G&amp;A</td>
<td>10,951</td>
<td>0.09</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL FIXED COSTS</strong></td>
<td>441,573</td>
<td>3.70</td>
<td>442</td>
<td></td>
</tr>
<tr>
<td><strong>CASH MARGIN</strong></td>
<td>1.06</td>
<td></td>
<td>126</td>
<td></td>
</tr>
</tbody>
</table>
The *PRISM* Simulator is a structured Microsoft® Excel workbook combined with an external linear programming solver used to optimize product blending. The refinery unit yield and cost assumptions are all exposed and can be easily modified by the user, if desired. The Simulator includes at least one of each of the major refinery units. In several cases, there are multiple unit models to allow dual train operations. Petrochemical unit models include steam cracking, aromatics extraction, cumene, and cyclohexane. The *PRISM* Simulator is also designed to allow customization by users including the addition of unit models not included in the standard version.

Capacities, configurations, crude slates, and operating parameters are maintained for each refinery in the *PRISM* Data Modules. These data are loaded into the Simulator for the refinery that is being analyzed. The standard *PRISM* Crude Assay Library includes detailed assay data for over 340 widely-traded and refined crude oils. The user can add additional crude oils, if desired.

Starting with the crude distillation unit, the *PRISM* Simulator models each process unit sequentially. Baker & O’Brien has established a standard process sequence, but the user is free to modify this sequence, if necessary, for any special-purpose study. Yields and detailed product qualities are calculated based on the individual refinery operating parameters retrieved from the Data Module, and feed properties are calculated in upstream unit models. Properties such as distillation, sulfur, PONA, Aniline point, viscosity, Conradson carbon residue, nitrogen, and metals are tracked in the Simulator.

The Simulator structure allows for recycle streams, and the standard Simulator includes several of these. The Simulator includes one of each type of refinery process unit. The standard Simulator is able to model any “fuels” refinery in the world, and the *PRISM* structure is flexible enough to allow customized Simulators, if required, for a special-purpose study. The procedure for cloning the standard Simulator and customizing it with additional process units, recycle streams, or modified yield correlations is easy and straight-forward.

While *PRISM* is primarily a non-linear, deterministic model, a linear programming optimizer is used to blend gasoline, distillate, and residual fuels. The Simulator includes the CARB-3 predictive model for gasoline blending.
**CRUDE ASSAY BLEND OPTIMIZER**

The *PRISM* Crude Assay Blend Optimizer uses an LP solver to blend crude to meet user defined crude properties. It is primarily used by crude oil traders to determine the most profitable mix of component crudes that will meet industry specifications for crude blends such as Louisiana Light Sweet (LLS) or West Texas Intermediate (WTI).

**CRUDE ASSAY DIRECTOR**

The *PRISM* Crude Assay Director is used to regress product property correlations from raw assay laboratory data for use with the *PRISM* Simulator. Because crude properties are stored in the *PRISM* Assay Library as a collection of correlation coefficients, crude cut points can be changed “on-the-fly” in the Simulator; it is not necessary to pre-cut crudes in an external assay tool. The Crude Assay Director is a user-friendly Microsoft® Excel workbook, and uses the Microsoft® Excel Solver to assist in regressing correlation coefficients.
CRUDE ASSAY VIEWER

The PRISM Crude Assay Viewer is a tool for displaying any of the assays in the PRISM Crude Assay Library. The Crude Assay Viewer includes graphs of all the major properties as shown below, plus a table showing the properties of individual crude cuts using user supplied cut points.

FIGURE 13

PRISM CRUDE ASSAY VIEWER

[Graph showing Kinematic Viscosity Blending Number (VBN) vs. VAPB, °F]
**TRADEMARK NOTICES**

*PRISM* is a trademark of Baker & O'Brien, Inc. All rights reserved.

Other trademarks are the property of their respective owners.
APPENDIX A. EUROPEAN DATA SERVICE (EDS) REFINERIES*

**Austria**
OMV-Schwechat

**Belarus**
Mozyr Oil-Mozyr
Naftan-Novopolotsk

**Belgium**
ExxonMobil-Antwerp
Gunvor (BRC)-Antwerp
Total-Antwerp
Vitol-Antwerp

**Bulgaria**
Lukoil-Burgas

**Croatia**
INA-Rijerka
INA-Sisak

**Czech Republic**
Czech Refining-Kralupy
Czech Refining-Litvinov

**Denmark**
Shell-Fredericia
Equinor-Kalundburg

**Finland**
Neste-Naantali
Neste-Porvoo

**France**
ExxonMobil-Fos-sur-Mer
ExxonMobil-Port Jerome/NDG
PetrolNeos-Lavera
Petroplus-Petit Couronne (2012)
Total-Donges
Total-Feyzin
Total-Grandpuits
Total-Normandy/Gonfreville L'Orcher
Total-Provence-La Mede (2012-2016)

**Germany**
Bayernoil-Vohburg/ Neustadt
BP-Lingen
Gunvor-Ingolstadt
Klesch-Heide
MiRO-Karlsruhe
OMV-Burghausen
PCK-Schwedt
BP-Gelsenkirchen
Shell-Godorf(Köln)/Wesseling
Shell-Harburg/Grasbrook
Tamoil-Holborn/Hamburg
Total-Spergau (Leuna)

**Greece**
Hellenic Petroleum-Thessaloniki
Hellenic Petroleum-Aspropygos
Hellenic Petroleum-Elefsina (2013+)
Motor Oil Hellas-Corinth (2013+)

**Hungary**
MOL-Száhalombatta

**Israel**
Oil Refineries Limited-Haifa
Paz-Ashdod

**Ireland**
Irving-Whitegate

**Italy**
ENI-Gela (2012-2013)
ENI-Sannazzaro
Lukoil-Prioli-Melilli
MOL-Mantova (2012-2013)
Raffineria di Milazzo-Milazzo
Saras-Sarroch
Sarpom (ExxonMobil/ERG)-San Martino di Trecate

**Lithuania**
PKN Orlen-Mazeikiu

*Except as noted, annual data are available for 2012 through 2017.*
Netherlands  
BP-Europoort  
ExxonMobil-Rotterdam  
Gunvor-Rotterdam  
Shell-Pernis  
Zeeland-Vlissingen  

Norway  
ExxonMobil-Slagen  
Equinor-Mongstad  

Poland  
PKN Orlen-Plock  
Grupa LOTOS-Gdansk  

Portugal  
GALP-Porto  
GALP-Sines  

Romania  
Rompetrol-Midia/Constanza  

Saudi Arabia  
SATORP-Jubail (2013+)  

Slovak Republic  
Slovnaft-Bratislava  

Spain  
ASESA-Tarragona  
BP-Castellon de la Plana  
IPIC-Cádiz  
IPIC-Huelva  
IPIC-Tenerife (2012-2015)  
Petronor-Vizcaya/Bilbao  
Repsol YPF-Cartagena Mucia  
Repsol YPF-La Coruna  
Repsol YPF-Puertollano  
Repsol YPF-Tarragona  

Sweden  
Preem-Gothenburg  
Preem-Brofjorden-Lysekil  
St1-Gothenburg  

Switzerland  
Tamoil-Collombey (2012-2014)  
Varo Energy-Cressier  

Turkey  
Tupras-Izmir-Aliaga  
Tupras-Izmit-Tutunciftlik  

Ukraine  
Ukrtransnafta-Kremenchug (2012-2015)  

United Kingdom  
Essar-Stanlow  
ExxonMobil-Fawley  
Murphy-Milford Haven (2012-2014)  
PetroIneos-Grangemouth  
Phillips 66-Humberside  
Total-Humberside  
Valero-Pembroke
APPENDIX B. ASIA-PACIFIC DATA SERVICE (APDS) REFINERIES**

** Except as noted, annual data are available for 2011 through 2017.

**APPENDIX B. ASIA-PACIFIC DATA SERVICE (APDS) REFINERIES**

**Australia**
BP-QLD-Brisbane/Bulwar Island (2011-2015)
BP-WA-Kwinana
CalTex-NSW-Kurnell (2011-2014)
CalTex-QLD-Lynton
ExxonMobil-VIC-Altona
Shell-NSW-Clyde (2011-2012)
Vitol-VIC-Geelong

**Canada**
Chevron-BC-North Burnaby

**Chile**
ENAP-Acocagua
ENAP-BioBio

**China**
PetroChina-Gansu-Qingyang-Lanzhou
PetroChina-Guangxi-Qinzhou (Yen Chow)
PetroChina-Liaoning-Dalian
PetroChina-Xinjiang-Dushanzi
Sinopec-Guangdong-Guangzhou
Sinopec-Guangdong-Maoming
Sinopec-Shanghai
Sinopec-Shanghai-Pudong-Gaoqiao
Sinopec-Tianjin-Dagang
Sinopec-Nanjing-Jinling
Sinopec-Zhenhai-Ningbo
Wepec-Liaoning-Dalian

**India**
Essar-Gujarat-Jamnagar/Vadinar
HMEL-Punjab-Bhatinda
Indian Oil Co-HR-Panipat
Mangalore Refinery-KA-Mangalore
Reliance Industries-Gujarat-Jamnagar SEZ
Reliance Industries-Gujarat-Jamnagar DTA

**Indonesia**
Pertamina-Borneo-Balikpapan/Kalimantan
Pertamina-Java-Cilacap

**Japan**
Cosmo-Chiba-Ichihara
Idemitsu Kosan-Chiba-Ichihara
JX Energy/PetroChina JV-Osaka-Takaishi
JX Holdings-Okayama-Mizushima-A (NOC)
Showa-Mie-Yokkaichi
Taiyo-Ehime-Kikuma-Shikoku
Tonen-Kawasaki-Keihin

**Malaysia**
Malaysian Refining-Melaka
Petronas-Melaka

**New Zealand**
New Zealand Refining-NI-Whangarei

**Philippines**
Petron: PHIL-Bataan-Limay

**Saudi Arabia**
SATORP-Jubail (2013+)

**Singapore**
ExxonMobil-Jurong/Pulau Ayer Chawan
Shell-Pulau Bukom
Singapore Refining-Pulau Merlimau

**South Korea**
GS Caltex-Yeosu
Hyundai Oil-Daesang
SK-Incheon
SK-Ulsan
S-Oil-Onsan

**Taiwan**
Chinese Petroleum-Dalin
Chinese Petroleum-Tao Yuan
Formosa Plastics-Mailiao

**Thailand**
SPRC-Rayong
Esso Thailand-Sriracha
Thai Oil-Sriracha
Vietnam
PetroVietnam-Dung Quat

United States

BP-Cherry Point, WA
Chevron-El Segundo, CA
Chevron-Richmond, CA
Island Energy-Barbers Point, HI
PBF Energy-Torrance, CA
Phillips 66-Ferndale, WA
Phillips 66-Santa Maria/Rodeo, CA
Phillips 66-Wilmington, CA
Shell-Anacortes, WA
Shell-Martinez, CA
Par-Kapolei, HI
Marathon-Anacortes, WA
Marathon-Carson, CA
Marathon-Kenai, AK
Marathon-Martinez, CA
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