

Energy Industry Trends and Insights from Wellhead to Downstream Products

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M³ — Measure. Manage. Maximize.®



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Solomon

We Benchmark the Oil & Gas Value Chain



- Exploration & Production
- Onshore Production
- Offshore Production
- FPSO
- SAGD



- Liquid Pipeline
- Natural Gas Pipeline
- Terminals
- Natural Gas & LNG Processing

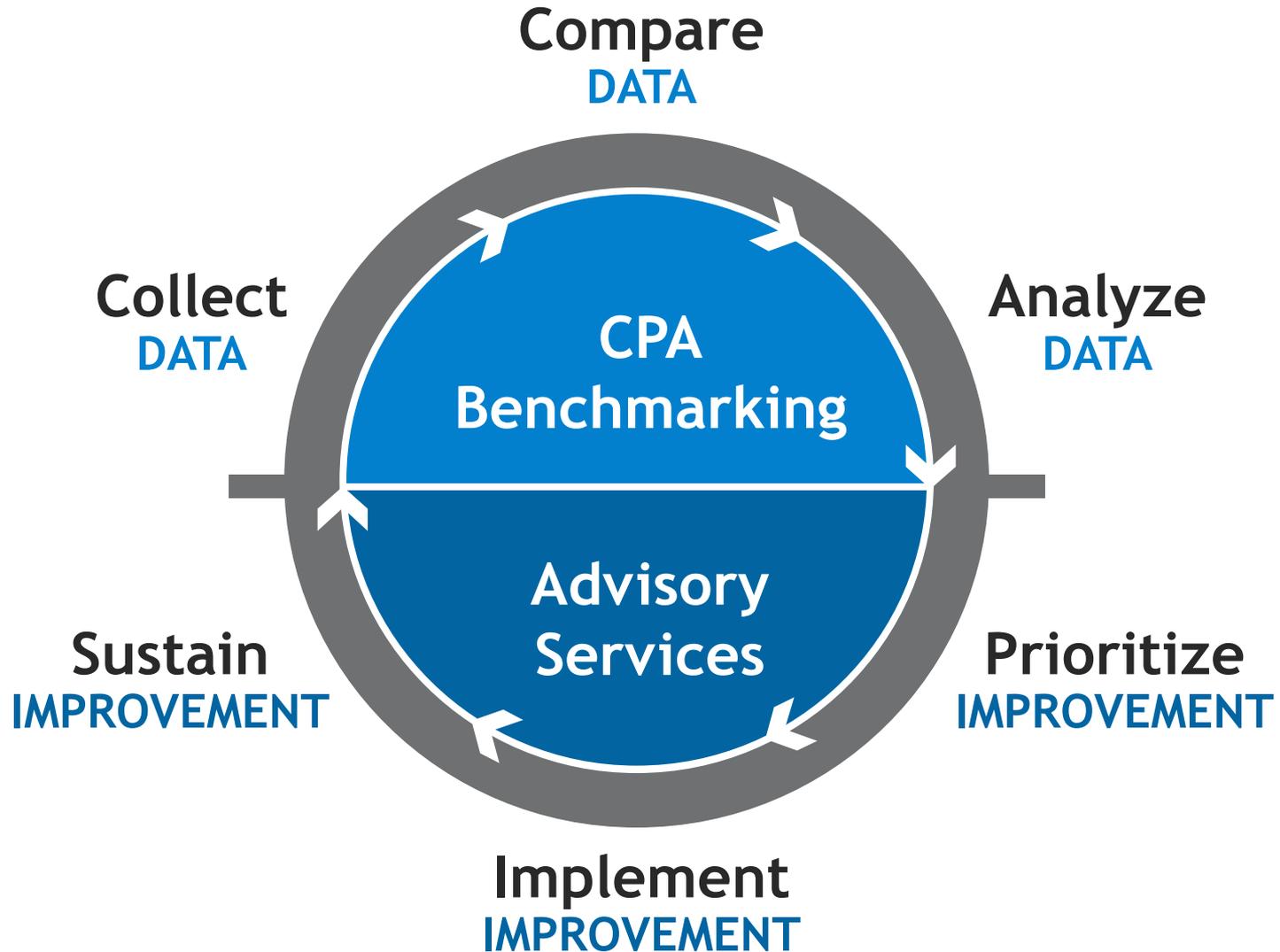


- Fuels & Lube Refining
- Petrochemicals
- Integrated Sites
- Reliability & Maintenance
- Power Generation

We see the trends of change: more than

95% of companies **repeat participation** study after study.

Solomon's Improvement Process



Solomon's Global Business Lines

Comparative Performance Analysis (CPA, Benchmarking)

Advisory Services (Consulting)

Solomon University (Training Services)

Solomon Profile (Performance Monitoring)

Global CPA Benchmarking Studies

Fuels Refining

Aromatics

Gas Processing Plants

Process Control

Integrated Site Complex

Lubes Refining

Petrochemicals

Liquid Pipelines

Automation

Power Generation

Terminals

Natural Gas Pipelines

Reliability & Maintenance

Upstream

**Companies in
more than**

70 countries rely

on Solomon; our metrics have become the standard for gauging performance around the world.



Agenda

**Solomon
The Early
Years**

**Growing into
Solomon
Of Today**

**Overview
of Study
Methods**

**Trends from
the Most
Recent Studies**

**Summary
and
Conclusions**

The Early Years: Solomon Associates, Inc.

Founded by Lee H. Solomon in 1981

One man



with an idea



and a Commodore 64 Computer



created a unique and elite company, known as the gold standard of benchmarking and consulting.

Solomon Now Part of Hartford Steam Boiler

HSB is Solomon Parent Company Since 1998

- Lee Solomon retired in 1998; sold company to HSB
- Became HSB Solomon Associates LLC, HQ in Dallas, Texas, USA



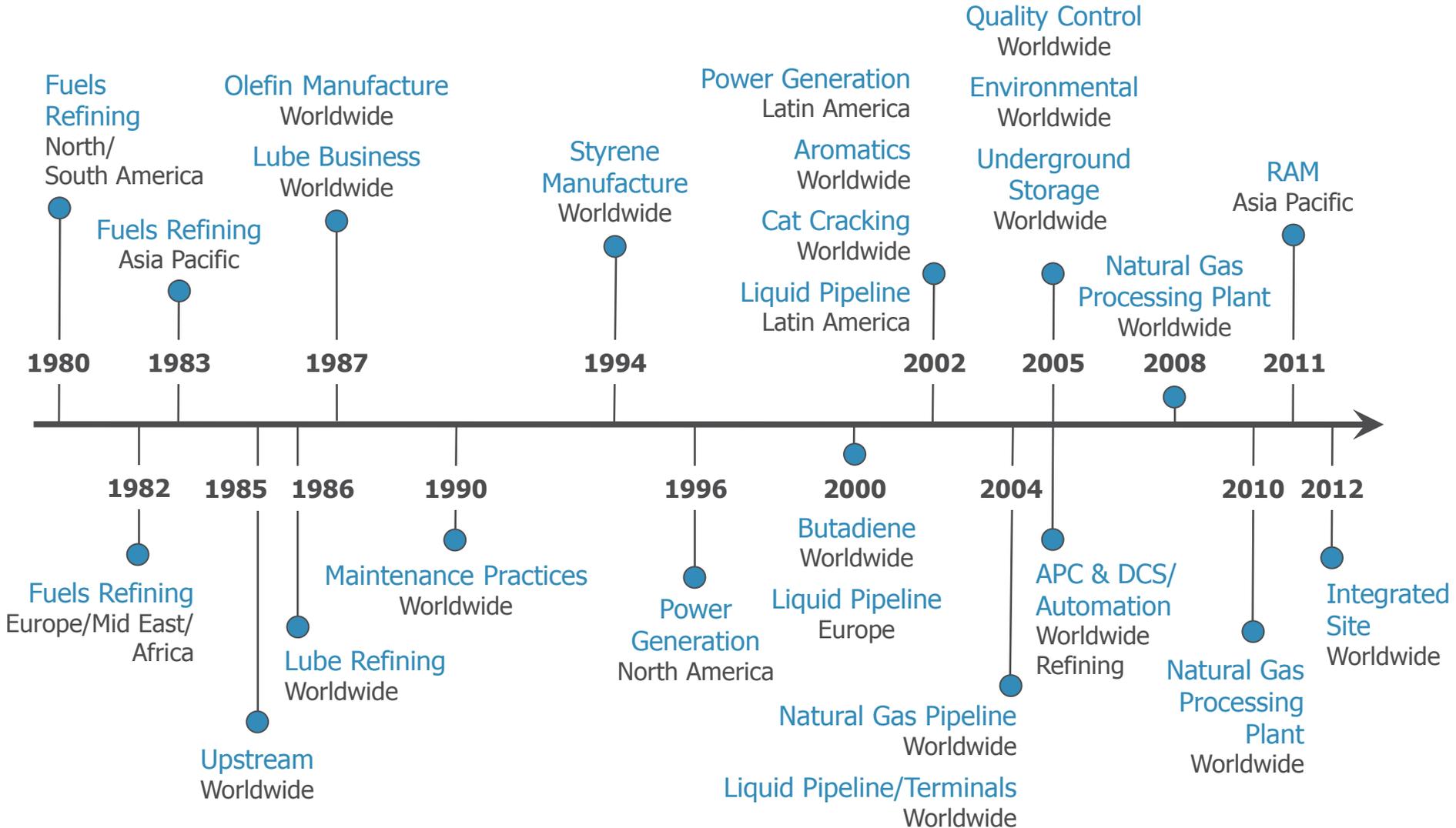
Known worldwide with name recognition throughout the industry, and even somewhat of an enigma to certain third parties...

He Really Does Exist!



Wow, I've never actually met anyone from Solomon before. You really do exist!

Timeline of Solomon Study Developments



What Was the Idea That Started It All?

All Refineries Are Different: How to Benchmark?

Equivalency Factors or Complexity Factors



- Break up refinery into sub-units
- Unit Complexity is a function of resources needed to operate and maintain that unit:
 - Energy
 - Maintenance
 - Work Hours
 - Operating Expenses
- Unit Complexity and other factors used to calculate **EDC[®]**
 - Represents Capacity plus Complexity, related to consumption of resources
- Similar analysis with energy consumption: **Energy Intensity Index[™] (EII[®])**
 - Predicted as a function of throughput and process severity for each unit
 - Compared to actual energy consumed
- Margin Gap Analysis compares each refinery to the best worldwide performers (Pacesetters)

Application of EDC/EII Methods to Other Studies

Complexity Factors Calculated from Solomon Database

Aromatics Study uses EDC/EII for Aromatics Process Units

Applied EDC/EII to Olefin Study in 2007, $r^2 = 0.96$

- Currently developing for EBSM (Styrene) Study, Polymer Addendum Study, Metathesis Study, and PDH Study (part of Olefin Study)

Natural Gas Processing/LNG Plant Study has EDC

Pipeline/Terminals Study has EPC™ and ETC™

- Equivalent Pipeline Capacity, $r^2 = 0.90$
- Equivalent Terminal Capacity, $r^2 = 0.88$

Power Generation Study has EGC™

- Equivalent Generation Capacity

Underground Storage Study has ESC

- Equivalent Storage Capacity

Upstream Studies: EDC in development (complexity-weighted barrel of oil equivalent)



EBSM = Ethyl Benzene and Styrene Monomer; PDH = Propane Dehydrogenation

Solomon Must Ensure Confidentiality and Trust

Strict Adherence to Protection Policies for Data and Intellectual Property

Studies conducted for benefit of participants

- Study reports not for sale to public
- Enforce strict rules on data release to and use of data by third parties

Major players in the following industries trust Solomon with their highly confidential operating data:

- Oil/gas production (upstream)
- Pipeline/terminal/underground storage, natural gas plants (midstream)
- Refining, petrochemical (downstream)
- Power generation (downstream)

Largest database of actual operating data in the oil & gas industry

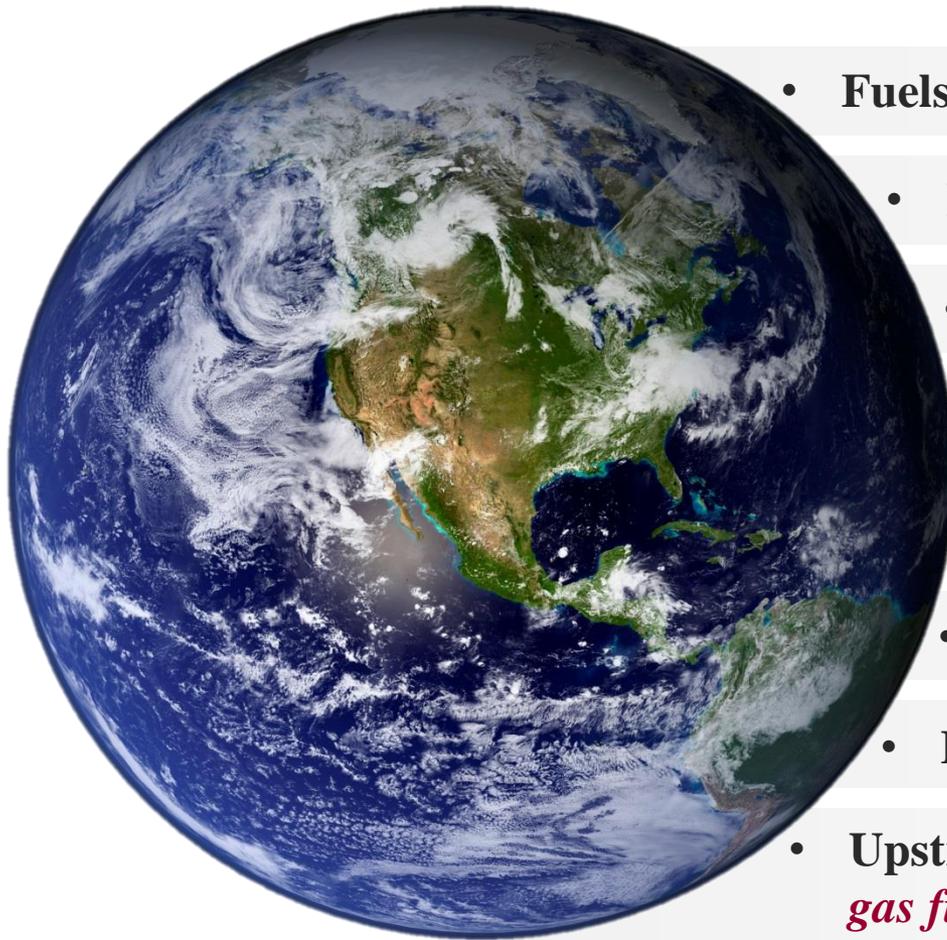
Database puts Solomon in unique position to advise clients regarding performance improvement, investment decisions, other projects

- Q1 Day 1 for new facilities: first quartile from first day of operations



Solomon CPA Clients Encompass the Globe

High Participation Levels in Solomon CPA Studies



- Fuels Study *300+ refineries*
- Lube Study *35+ refineries*
- Olefin Study *120+ plants*
- Terminal Study *175+ terminals*
- Pipeline Study *125+ pipelines*
- Natural Gas Plant Study *60+ plants*
- Power Generation Study *400+ units*
- Upstream *>5,000 onshore & offshore oil & gas fields in >40 countries*



Other Topics to Consider: Details, Details, Details

Analysis of Data Must Consider These Elements

- Changing Currency Exchange Rates vs USD, euro, or other reference
- Relative Inflation by Country
- Engineering & Construction Cost relative to USGC or other reference
- Wage rates, material costs from country to country, region to region
- Relative facility size, economy of scale (or lack thereof)
- Track hundreds of market prices
 - Crude Oil, Refined Products (Fuels)
 - Downstream Feeds
 - Downstream Products
 - Energy
- Transportation/logistics costs
- Keep up with technology



USD = United States dollars; USGC = US Gulf Coast

Highlights and Trends from Most Recent Solomon Studies



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Fuels Refinery Study – Since 1980

Most Recent Completed Study for Year 2014 (2016 in progress)



- 313 fuels refineries participated in 2014 Fuels Study, ~85% of eligible refining capacity
- Operating expense is 55% energy in Europe, 70% energy in Asia
 - Maintenance is top category of expense in >60% of US/Canada
- US/Canada produce more high-value products (e.g., gasoline, jet, diesel, and heating oil) at ~80% vs 68% for rest of world
- In constant USD, global maintenance cost increased 7.6% from 2012; US/Canada increase was double that
- Energy as measured by EII (actual energy/Solomon standard energy × 100) improved by 0.5% to 1% per year 2008 to 2014
- Low energy prices in North America revived its refining industry; European refineries under pressure
- Insufficient skilled labor is worldwide problem for refining



Lube Refinery Study – Since 1986

Most Recent Completed Study for Year 2014



- Global oversupply causing lower utilization of all base oil refineries, continuing into 2016
- Higher availability, increasing supply (new construction) and lower demand, expected to continue for several years, likely more rationalization
- Refineries moving feedstocks from lube units to conversion units making more fuels, less lube oil
- Some base oil producers adjusting product slate to produce higher-viscosity grades and more waxes where possible
- Refinery focus is on lowering operating expense to survive in current tough environment



Olefin Study – Since 1987

Most Recent Completed Study for Year 2015

- 118 olefin plants from 46 companies in 30 countries, ~60% of global eligible capacity
- Global average ROI nearly the same in 2013 & 2015; those two studies showed highest global average ROI in 25 years
 - Asia doubled 2013 ROI on higher product prices, lower feed cost
 - North America ROI fell 17 points from 2013 on lower product value
- Global ethylene utilization improved ~3 percentage points 2011–2015
 - Production loss to “lack of demand” outages cut in half 2013 to 2015
- Light feed (C₄ and lighter) grew from global average of 34% of feed to 47% 2011–2015; North America average now >80%
- Maintenance cost rising from 2% RV in 2011 to 2.5% for 2015
 - North America had largest increase of all regions, rising 58% since 2011
- Participation in Polymer Addendum Study growing



ROI = return on investment; RV = replacement value

Styrene Study – Since 1994

Most Recent Completed Study for Year 2015 (Asia)

Includes Ethyl Benzene (EB) and Styrene Monomer (SM) production units, also known as EBSM Study

Study results provided for EB, SM, and combined EBSM units

Asian plant utilization performance for both EB and SM units improved from prior study

Asian plant maintenance spending levels rising

Developed EDC, EII for EBSM Study in 2015



Aromatics Study – Since 2002

Most Recent Completed Study for Year 2014 (2016 in Progress)

- Included 85 aromatics complexes worldwide
- Combines aromatics units included in Fuels Study with those based on petrochemical sites
- Asia/Pacific region led in many metrics due to continued growth
 - Average capacity 50% bigger; average age 25% lower than Total Study Average
 - Higher utilization and most energy efficient
- No difference in reliability averages across regions
 - Planned turnarounds are largest component of maintenance downtime
- Energy 80% of OpEx in Asia vs only 45% of OpEx in N America
- 2016 Study (currently in data-gathering phase) will give clear picture of how feed, product, energy costs, and markets affected regional competitiveness

OpEx = operating expense



Power Generation Study – Since 1996

Most Recent Completed Study for Year 2015

120+ sites with ~450 generation units, capacity nearly 190 GW –

- Fueled by natural gas, oil, coal
- Combined cycle (steam turbine, combined heat and power)
- Simple cycle gas turbine

Trends observed 2010–2015

- Power Block commercial unavailability runs 13–14%
- Start reliability increased from 74% to 80%
- OSHA recordable safety incidents dropped 43%
- Renewal maintenance dropped from 1.85 to 1.17 USD/MWh
- Major equipment overhaul interval increased for boilers, steam turbines, combustion turbines (~20%)

Renewables gaining more of electric power market

- Lower revenue for generators resulted in lower maintenance spend & delayed renewal capital on fossil-fuel generation
- Could reduce availability and reliability of grid-supplied power



GW = gigawatts; USD/MWh = US dollars per megawatt-hour

Liquid Pipeline Study – Since 2000

Most Recent Completed Study for Year 2015

- 129 liquid pipeline systems, global representation
 - Crude and other “black” oils – 72
 - Refined products and condensate – 57
- Company plus contractor personnel cost is 70% of Fixed OpEx
- Maintenance capital is 27% of Fixed OpEx
- More than 50% of participants use drag-reducing agents (DRAs)
 - DRA cost plus energy cost (volume-related cost) is 24% of OpEx
- Age not a good predictor of cost – very poor correlation: 0.005 r^2
- Cost of Integrity Management Programs (IMPs, part of major maintenance) up significantly since 2010 for North & South America
 - Most of the Americas’ IMP costs are repair/reconditioning



Terminal Study – Since 2004

Most Recent Completed Study for Year 2015

- 179 total terminals: Pipeline Only, Non-Marine, Marine
- Operating and maintenance costs ~60% of OpEx
 - Energy costs average less than 10% of OpEx
- Labor-intensive: company plus contract employee cost is 70% of controllable costs
- High-cost maintenance items (maintenance capital) 10% of total maintenance cost
- Inspection cycle for most tanks is 12+ years
- Marine terminals have >3× tankage of pipeline-only terminals but only have 30% greater throughput
- Best performers have higher work hours, especially for maintenance
 - More realistic sustainable performance



Upstream (Oil & Gas) Studies – Since 1985

Most Recent Analysis 2017 (Retainer Client Base)

Worldwide Tight Oil Analysis

Tight oil is oil trapped in shale and light sandstone

- Reserves identified outside North America (worldwide)
- Won't see tight oil recovery there as in North America for at least 10 years
- May need new/different technologies outside North America
- High entry costs due to need for infrastructure development

Tight oil recovery can be ramped up quickly using horizontal drilling

Producers working to reduce costs since oil price drop at end of 2014

In North America, tight oil produced is “lighter” than previously imported Saudi and Latin American crude

- Requires refinery processing configuration change



Reliability & Maintenance (RAM) Studies – Since 1990 Most Recent Completed Study for Year 2015

- Hundreds of sites from refining, petrochemicals, other chemicals in RAM database
- Data analyzed by process family, chemical family, and utilities
- Overall best performance measured by combination of maintenance cost and value of production loss due to unreliability
- Q1 performers' reliability ultimately drives lower costs
 - Spending is the result of their reliability, not driver of their reliability
 - Perform optimal turnarounds (TAs) so that they have limited or no downtime during non-TA periods
 - Have lowest total downtime attributed to TA
 - Are continuing to improve in performance year on year
 - Have established predictive and preventative plans so that fixed equipment is not a cause of failure during non-TA periods



Questions?



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Thank You!

Improving
Competitive Performance
around the world.



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