Wait...What?

US Inventories - Crude and Key Products

- Positive overall trend since earlier this year.

Max
Median
Min

Wait...What?
OECD Inventory Trends...Bullish!

- Max / 2016
- yr-5 Norm
- Min

Million Barrels

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

2017

2,400  2,900  3,400
Northern Midland Productivity Analysis

This analysis is only done using wells that are producing from the Wolfcamp with Lateral Length > 3,000 ft, proppant loading > 100 lbs/ft, and fluid loading > 1 bbl/ft.

Source: IHS Enerdeq, TPH Research
This analysis is only done using wells that are producing from the Wolfcamp with Lateral Length > 3,000 ft, proppant loading > 100 lbs/ft, and fluid loading > 1 bbl/ft.

Source: IHS Enerdeq, TPH Research
This analysis is only done using wells that are producing from the Wolfcamp with Lateral Length > 3,000 ft, proppant loading > 100 lbs/ft, and fluid loading > 1 bbl/ft.

Source: IHS Enerdeq, TPH Research

*Normalized to 5,000’ wells.
This analysis is only done using wells that are producing from the Wolfcamp with Lateral Length > 3,000 ft, proppant loading > 100 lbs/ft, and fluid loading > 1 bbl/ft.

Source: IHS Enerdeq, TPH Research
# Oil and Gas Opportunity

<table>
<thead>
<tr>
<th>Surface</th>
<th>Artificial Lift</th>
<th>Completions/Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics</td>
<td>80-90% of wells are on lift</td>
<td>Inverse problem</td>
</tr>
<tr>
<td>Sensors</td>
<td>Marginal wells accounted for 11-18% of US production</td>
<td>Capabilities need to be unlocked by acquiring more data</td>
</tr>
<tr>
<td>Internet of Things</td>
<td>Gas lift vs. Rod Pump vs. ESP’s</td>
<td>Industry is focusing on IP rates vs. drainage area</td>
</tr>
<tr>
<td>Predictive maintenance</td>
<td>Conventional methods being used on unconventional wells</td>
<td></td>
</tr>
<tr>
<td>- Lower LOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Higher Uptime</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

More Data & Sensors  ➔  Less Data & Sensors

> “I know that you’re afraid... You’re afraid of change. I don’t know the future. I didn’t come here to tell you how this is going to end. I came here to tell you how its going to begin.”

- Neo, The Matrix
Big Data: Why Now?

- Land Grab is over
- Returns Matter
- Well Performance Plateau
- Old Tools Inadequate
- Inverse Problem Solved with Data

“Never send a human to do a machine’s job”
- Agent Smith, The Matrix
## The Inverse Problem

The Model is Uncertain... Use Inputs/Outputs to Define

- Solves for parameters that are not directly observable
- The more data that is acquired, the clearer the picture becomes
- Define the model using the inputs and outputs

- Larger data sets = faster model definition
- This drives completion design and reservoir management
- With more data, the reservoir comes into focus, but is never perfectly clear

### The More Information Obtained, The clearer the Picture

```
<table>
<thead>
<tr>
<th>Initial State</th>
<th>Improving Data</th>
<th>Final State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

“You can argue with me, but you can’t argue with figures!”

- Foghorn Leghorn, Looney Tunes
Completions: Where Every Stage Should Matter

Studies on Hydraulic Fracturing Stages Non-Productivity

- SLB study showed 15-20% of fracture stages do not contribute
  - 35-40% of perforation clusters
- Numerical simulations estimate up to 75% of hydraulic fractures don’t contribute
- We don’t know why

“Determining the Number of Contributing Fractures in Shale Gas Wells with Production Analysis and Proppant Tracer Diagnostics”
-The Society of Petroleum Engineers (2015)

“Operators Seek Fracture Consistency”
-The American Oil & Gas Reporter (January, 2012)
Reservoir (Not Well) Optimization

Focused on Field Level Returns

- Important Variables
  - Well Spacing
  - Frac Intensity & Size
  - Well interference

- Companies are high grading their production portfolio
  - Drilling high return wells and setting aside low return wells

Well Spacing in Karnes County, Texas

“Ah... It’s a profit deal”
- Navin Johnson, The Jerk
Old Tools Aren’t Working Anymore

Current “Technology”

- “Optimize Wells”
  - Bigger Hammer - Longer laterals, more sand, more stages
  - Frac Theory? “Welcome to 1992”

- Challenges
  - Well results plateauing
  - Bigger Hammer not working
  - Cannibalizing IRR

Old Tools Don’t Work

- Stimulation of 50 stage horizontal well... GOOD LUCK!
- Need differentiated approach
- Enter BIG DATA!

Drilling and Completions Evolution

<table>
<thead>
<tr>
<th>Drilling Cost per Total Depth</th>
<th>Lbs Proppant per Lateral Foot</th>
<th>N.A. Avg. Fluid, Proppant and Stages</th>
</tr>
</thead>
</table>

- **Eagle Ford**
- **Bakken**
- **Marcellus**
- **Midland**
- **Delaware**

- **Average of Gallons fluid**
- **Average of total Proppant lbs**
- **Average of Number of Stages**
Find What Is Missing In This Picture

### Machine Intelligence 3.0

<table>
<thead>
<tr>
<th>Visual</th>
<th>Audio</th>
<th>Enterprise Intelligence</th>
<th>Internal Data</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent Enablers</td>
<td>Data Science</td>
<td>Machine Learning</td>
<td>Natural Language</td>
<td>Research</td>
</tr>
</tbody>
</table>

### Customer Support

<table>
<thead>
<tr>
<th>Enterprise Functions</th>
<th>Security</th>
<th>Recruiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Support</td>
<td>Marketing</td>
<td>Sales</td>
</tr>
</tbody>
</table>

### Autonomous System

<table>
<thead>
<tr>
<th>Ground Navigation</th>
<th>Aerial</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous System</td>
<td>Sensor</td>
<td>Data Science</td>
</tr>
</tbody>
</table>

### Agriculture

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Education</th>
<th>Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industries Cont’d</td>
<td>Investment</td>
<td>Legal</td>
</tr>
</tbody>
</table>

### Material

<table>
<thead>
<tr>
<th>Materials</th>
<th>Retail Finance</th>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare</td>
<td>Biological</td>
<td>Image</td>
</tr>
</tbody>
</table>

### Technology Stack

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Open Source Libraries</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Biological</td>
<td>Image</td>
</tr>
</tbody>
</table>

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**Tudor Pickering Holt & Co.**

14
TPH Senior Energy Tech Team

John W. Gibson, Jr.  
*Managing Director*

- Former President and CEO Tervita, Paradigm Geophysical, Halliburton, Landmark Graphics
- Director / Audit Chair of multiple energy tech companies:
  - High pulse power company, I-Pulse Inc.
  - Lithium and Mineral resource company, Orocobre Limited
- University of Houston’s Energy Advisory Board
- Visiting Committee of the Texas Bureau of Economic Geology
- Advisor to Cottonwood Venture Partners, an Energy Tech Venture Capital Fund
- On the USC Global Energy Network Advisory Board
- 10+ years of experience working for Gulf / Chevron, running R&D initiatives
- BS Geology from Auburn University
- MS Geology from University of Houston

David A. Pursell  
*Partner*

- Former Head of TPH Macro Research
- Investment Committee Member of Whipstock Co-Investment Fund, Private Energy Opportunities Fund and TPH Partners LP
- Board Member of Channel Energy and Mustang Resources
- Founding Partner of Pickering Energy Partners, the predecessor firm to Tudor, Pickering, Holt & Co.
- Director of Upstream Research at Simmons & Company
- Over eight years as Petroleum Engineer at S.A. Holditch & Associates, now a division of Schlumberger
- Over four years as Field Engineer at ARCO Alaska, Inc., with hydraulic fracturing experience
- BS / MS in Petroleum Engineering from Texas A&M University
Is Conventional Oil and Gas Investing Still Relevant?

TPH has engaged the question around long-term relevance of conventional energy by launching a dedicated Energy Tech group to advise clients on potential disruptions in the industry.

TPH has also extended its Research and Asset Management coverage to include companies and topics at the forefront of the discussion.

“Norway’s Wealth Fund Considers Divesting From Oil Shares”

“How much Growth Is Left In Oil and Gas?”
- Simply Wall St. (Oct. 28, 2017)

“Adapt Or Die: Oil Majors In The New World”

“Norway powers ahead (electrically): over half new car sales now electric or hybrid”
- Reuters (Jan. 3, 2018)

“China and India on Aggressive Electric Vehicle Push”
- Nasdaq (May 25, 2017)

“California officials blast Trump’s oil-drilling proposal as dangerous and unneeded”
- Los Angeles Times (Jan. 4, 2018)

“Clean Energy Soared in the U.S. in 2017 Due to Economics, Policy and Technology”
- Inside Climate (Jan. 3, 2018)

“Michigan pushing to increase renewable energy resources”
- Up North Live (Jan. 5, 2018)

“China and India on Aggressive Electric Vehicle Push”
- Nasdaq (May 25, 2017)
What are the Issues?

**Global Oil Demand Increasing**

*Oil demand has increased 22 of the last 24 years*

<table>
<thead>
<tr>
<th>Year</th>
<th>Real GDP CAGR</th>
<th>Oil Demand CAGR</th>
<th>Oil Change / GDP Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-Yr</td>
<td>1.4%</td>
<td>2.9%</td>
<td>0.48</td>
</tr>
<tr>
<td>10-Yr</td>
<td>1.2%</td>
<td>2.1%</td>
<td>0.56</td>
</tr>
<tr>
<td>5-Yr</td>
<td>1.5%</td>
<td>3.4%</td>
<td>0.43</td>
</tr>
<tr>
<td>1-Yr</td>
<td>1.4%</td>
<td>3.2%</td>
<td>0.44</td>
</tr>
</tbody>
</table>

**“Hot Button” Issues Around Peak Oil Demand**

- **Renewable Displacement**
  - Wind and Solar electric generation has the potential to impact conventional consumption of natural gas and coal on the domestic grid over the next 3 to 5 years

- **Electric Vehicles**
  - Increased adoption of electric vehicles to displace oil product demand (gasoline/diesel) from conventional combustion engines

- **Autonomous Vehicles / Sharing Economy**
  - Developing technology around self-driving vehicles and the ability to share with multiple parties may reduce need of existing fleet size over the next 5 to 10 years

- **Regulation**
  - Renewable energy standards, fleet efficiency mandates, carbon taxes, and similar regulations could materially alter the operating environment

- **Emerging Economies**
  - Developing economies (China, India) could modernize their consumption patterns in materially different ways than the developed world

Source: IEA, IMF
E-Tech is the Intersection of Silicon Valley and Oil & Gas

The above listed companies are shown for illustrative purposes only.
How TPH is Thinking about Tech

**Conventional Energy**

- **Upstream:** *Adaptors v. Laggards*
  - Traditional upstream business will be overturned as the old tools that provided growth no longer work
  - Sector will be bifurcated by Adaptors and Laggards as those who successfully leverage technology displace high-cost operators

- **Services:** ‘*Technological Gems’ v. ‘Dumb Iron’*
  - Reduction in industry R&D spending will disaggregate the service sector
  - ‘Dumb Iron’ companies will lose relevance to those with specialized technology

**Displacement Technologies**

- **Renewable Generation & EVs:** *Better / Cheaper or Mandated*
  - Renewable Generation / EV adoption rate will be determined by:
    1) Step-change in battery technology (Vehicles in conjunction with Grid Storage)
    2) Regulatory-driven behavior / market changes
It is Happening, Now It is a Question of Magnitude

TPH will remain at the forefront of the industry’s evolving landscape through its expanded research effort and dedicated advisory team.

- **Digital**
  - Big Data
  - Predictive Analytics
  - Storage
  - Computing
  - Cloud Solutions
  - Video
  - Machine Learning
  - Artificial Intelligence
  - Drones

- **Cleantech**
  - Water Disposal
  - Waste Reduction
  - Abandonment
  - Emissions Control
  - Monitoring & Compliance
  - Water Purification
  - Waste of energy

- **Efficiency**
  - Robotics
  - Automation
  - Internet of Things
  - Commercial Phone Applications
  - Personalized Learning Environment
  - Shared Data / Computing
  - 3D Printing

- **Subsurface**
  - Stimulation Design
  - Stimulation Monitoring
  - Completions
  - Nano-Solutions
  - Electromagnetic Monitoring
  - Geo-mechanics
  - Pumps
  - Chemicals
  - Sensors

- **Alternative Energy**
  - Wind
  - Solar
  - Fuel Cells
  - Energy Storage
  - Biofuels

---

TUDOR PICKERING HOLT & CO
Energy Tech is not a Distinct Sector...
... but has Applications across the Energy Value Chain

<table>
<thead>
<tr>
<th>Energy tech is positioned to disrupt all sub-sectors of the industry</th>
<th>Upstream</th>
<th>Midstream</th>
<th>OFS</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digital</strong></td>
<td>Applied software and algorithms use AI and Machine Learning to analyze vast datasets</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Cleantech</strong></td>
<td>Techniques and equipment to recycle water, heat, and waste</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>Automation and robotics to collect field data through the Internet of Things and remove human error</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Subsurface</strong></td>
<td>Downhole analytics, chemicals, and completions techniques to increase production</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Alternative Energy</strong></td>
<td>Next generation power sources, storage techniques and conversion</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Industry Approach & Case Studies
Industry Approach is Fragmented and Evolving

Recent Technology Strategies

Technology adoption is dependent on C-suite implementation and company culture

Corporate Tech Investment Strategies

- Small / mid-size operators have flexibility to accelerate change
  - Seed capital for early stage companies
  - Provide projects (revenue) for early stage companies
  - Migrating meta-data to the cloud
- Major companies, such as Chevron, have Venture Capital Funds to invest in technology startups

Internal Tactical Approach

- Companies may buildout expertise organically:
  - Build in-house expertise / data warehouses
  - Outsource computing capabilities
  - Hybrid / combinations
  - Focus on surface, artificial lift, and downhole aspect of wells / reservoirs
- EOG has completely developed their IT infrastructure in-house with their own proprietary data

Targeted Technology Solutions

- Strategies to-date have focused on surface control / optimization
  - Drilling & production enhancements
  - Predictive maintenance on surface & downhole tools
  - Reservoir management
- Artificial Intelligence algorithms, such as those provided by Novi Labs, help engineers properly space wells and design completions to exploit their acreage
Energy Tech Case Study

Google Cloud Platform

<table>
<thead>
<tr>
<th>Company Profile</th>
<th>SLB’s Petrel Software is Run On The Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company Description</strong></td>
<td><strong>Company Description</strong></td>
</tr>
<tr>
<td>Google Cloud is a web based big data repository with artificial intelligence and machine learning capabilities</td>
<td>SLB’s Petrel Software is Run On The Cloud</td>
</tr>
<tr>
<td><strong>Market Capitalization</strong></td>
<td><strong>Market Capitalization</strong></td>
</tr>
<tr>
<td>$763 Billion</td>
<td>Market Capitalization</td>
</tr>
<tr>
<td><strong># of Employees</strong></td>
<td><strong># of Employees</strong></td>
</tr>
<tr>
<td>75,000</td>
<td># of Employees</td>
</tr>
<tr>
<td><strong>Headquarters</strong></td>
<td><strong>Headquarters</strong></td>
</tr>
<tr>
<td>Mountain View, CA</td>
<td>Headquarters</td>
</tr>
</tbody>
</table>

Artificial Intelligence and Machine Learning Capabilities

- SLB partnered with GCP to launch their DELFI cognitive E&P software and data lake
- SLB uses features such as Google BigQuery, Cloud Spanner and Cloud Datastore
- SLB now utilizes the GCP to run its petrotechnical software such as Petrel
- Geophysical data is now able to be processed at speeds that drastically outpace traditional data centers
- Super computers with capabilities of 35 petaflops of CPU and 10 petabytes of storage
- Cloud based computing allows for access to data anywhere at anytime
- SLB leverages AI and Machine Learning to automate well-log quality control
- AI allows for 3D seismic interpretation and extrapolation between wellbores
- GCP allows for SLB’s clients to upload their proprietary information

Source: Google
## Energy Tech Case Study

### EOG Resources

<table>
<thead>
<tr>
<th>Company Profile</th>
<th>Technology Centric Company Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company Description</strong></td>
<td><strong>Culture</strong></td>
</tr>
<tr>
<td>Diversified independent focused on unconventional resources</td>
<td>Rate-of-Return Driven</td>
</tr>
<tr>
<td><strong>Market Capitalization</strong></td>
<td>First Mover Advantage</td>
</tr>
<tr>
<td>$64 Billion</td>
<td>Decentralized / Non-Bureaucratic</td>
</tr>
<tr>
<td><strong># of Employees</strong></td>
<td>Multi-Disciplined Teamwork</td>
</tr>
<tr>
<td>2,650</td>
<td>Innovative / Entrepreneurial</td>
</tr>
<tr>
<td><strong>Headquarters</strong></td>
<td>Every Employee is a Business</td>
</tr>
<tr>
<td>Houston, TX</td>
<td></td>
</tr>
</tbody>
</table>

### Tech Led Approach Unlocks Resources with Less Rock

- **EOG Delaware Basin**
- **Delaware Basin Peers**
- **Midland Basin Peers**

<table>
<thead>
<tr>
<th>Recent Energy Tech Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proprietary Data</strong></td>
</tr>
<tr>
<td>EOG collects and compiles their own comprehensive, integrated, and accessible data sets</td>
</tr>
<tr>
<td>Database of over 5,000 wells including data over the lifetime and phases of each well</td>
</tr>
<tr>
<td>In-house big data architecture and data science platform</td>
</tr>
<tr>
<td><strong>Industry Leading Data Delivery Systems</strong></td>
</tr>
<tr>
<td>Over 65 mobile and desktop applications to visualize the company’s operations</td>
</tr>
<tr>
<td>Real-time data that is accessible at anytime, anywhere</td>
</tr>
<tr>
<td>Each app is designed by the respective department, but is accessible to everyone in the company</td>
</tr>
<tr>
<td><strong>Company Culture</strong></td>
</tr>
<tr>
<td>C-Suite acceptance and top down implementation</td>
</tr>
<tr>
<td>Technologies have been built upon over three decades</td>
</tr>
<tr>
<td>Continual innovation, experimentation, and learning</td>
</tr>
</tbody>
</table>

---

Source: EOG Resources
## Energy Tech Case Study

**Chevron**

### Company Profile

<table>
<thead>
<tr>
<th>Company Description</th>
<th>Integrated oil and gas company that operates in the upstream and downstream segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Capitalization</td>
<td>$243 Billion</td>
</tr>
<tr>
<td># of Employees</td>
<td>55,200</td>
</tr>
<tr>
<td>Headquarters</td>
<td>San Ramon, CA</td>
</tr>
</tbody>
</table>

### Central Data Center

- **Faster Data, Less Drilling Time**
  - Collecting real time data to make decisions remotely and efficiently for management and the field
  - Provides a line of communication between geologists and the rig
  - Geo-steering wells into the targeted optimal formation

- **Predictive Analytics**
  - Chevron’s Machinery and Power Support Center (MPSC) remotely monitors >1,000 pieces of equipment
  - Applies predictive models to anticipate failures or maintenance needs and prevent shutdowns
  - Reduce non-productive time of equipment and personnel

- **Microseismic Monitoring**
  - Real-time monitoring of fracture treatments
  - Helps detect where fractures are propagating and the productivity of each stage
  - Used to optimize completion designs

---

Source: Chevron
Current Industry Challenges

<table>
<thead>
<tr>
<th>Limited Data Sets</th>
<th>Plateauing of Parameters (i.e., Diminishing Returns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Data limited to surface collection methods</td>
<td>• Longer Laterals</td>
</tr>
<tr>
<td>• Current implementations for downhole measurements are cost and opportunity prohibited</td>
<td>• Fracturing more stages</td>
</tr>
<tr>
<td>- Running sensors or wires on casing - rotational issues</td>
<td>• Pumping more proppant and water per stage</td>
</tr>
<tr>
<td>- Wired drill pipe - cost prohibitive</td>
<td>• Studies by SLB show that 15-20% of fracture stages and 35-40% of perforation clusters do not produce</td>
</tr>
<tr>
<td>• IntelliServ Wired Drill Pipe has been used to drill wells with multiple challenges such as fluid losses, influxes, unstable formations, and excessive downhole shock and vibration to capture data traditional telemetry tools cannot</td>
<td></td>
</tr>
</tbody>
</table>

Old Tools Aren’t Working Anymore

<table>
<thead>
<tr>
<th>Quest for Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Realized productivity improvements have come from:</td>
</tr>
<tr>
<td>- Longer laterals and the innovations making this possible</td>
</tr>
<tr>
<td>- Increased frac density</td>
</tr>
<tr>
<td>• Conventional tools (rod pumps, gas lift, etc.) have reached limits for unconventional resources</td>
</tr>
<tr>
<td>• Rod pumps, ESP’s, and gas lift work best in a uniform vertical column of fluid but as the well depletes fluid levels fall creating inefficiencies</td>
</tr>
<tr>
<td>- Hills and valleys in the horizontal part of a well allow oil and gas to accumulate or create slugging flow, which negatively affects lift equipment</td>
</tr>
<tr>
<td>• Industry needs new tools to unlock the step-change in efficiency</td>
</tr>
<tr>
<td>• Energy is ripe for application of “Big Data” solutions</td>
</tr>
<tr>
<td>- Highly fragmented</td>
</tr>
<tr>
<td>- Large data sets</td>
</tr>
<tr>
<td>• Regardless of ultimate solutions, quality data and efficient analytics will allow engineers and industry professionals to create value and reduce spending</td>
</tr>
<tr>
<td>• Welder E&amp;P saved $340,000 in OPEX, decreased downtime by 50%, and increased revenue by $265,000 in their South Texas field by implementing connected sensors and data analytics</td>
</tr>
</tbody>
</table>

Source: TPH Research
How We Got Here

Current Drivers of Energy Tech Disruption

**The industry needs a step-change in technology to reduce costs in today’s price environment**

<table>
<thead>
<tr>
<th>Low Oil Prices Have Restricted Energy Cash Flows</th>
<th>Worldwide Fossil Fuel R&amp;D Spend Declining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced cash flow drives need for enhanced technology</td>
<td>Industry must innovate more with less money</td>
</tr>
</tbody>
</table>

**U.S. Shale Land Grab is in Final Stages**

*Core acreage is captured; Focus shifting to exploitation*

**Current Technology Limits Are Being Realized**

*What will drive the next step-change?*

---

Source: IEA
Electric Vehicle Deep Dive
Electric Vehicle Overview

- Vehicle miles traveled (VMT) showed 3% annual growth since 1970 despite recession and high gasoline prices
- Consumer behavior has resulted in slow fuel economy efficiency gains fleet wide of 0.5% annually
- EVs are not a near/medium-term threat to crude oil and gasoline demand as they are only 0.85% of global/US market share
- Assuming the US light vehicle fleet was swapped in its entirety for plug-in electric vehicles (PEV’s) tomorrow:
  - US oil demand would decrease by nearly 50%
  - Electricity demand would increase by 25%
  - Natural gas demand would increase by 27%
- Dramatic and consistent annual sales gains would be required to replace attrition, consumer behavioral change, and significant infrastructure buildout

Base Case: 2 MM units P.A. by 2027

<table>
<thead>
<tr>
<th>MPG</th>
<th>0</th>
<th>0.5%</th>
<th>1.0%</th>
<th>1.5%</th>
<th>2.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMT-1%</td>
<td>8.2</td>
<td>7.7</td>
<td>7.3</td>
<td>6.9</td>
<td>6.6</td>
</tr>
<tr>
<td>0%</td>
<td>9.1</td>
<td>8.6</td>
<td>8.2</td>
<td>7.7</td>
<td>7.3</td>
</tr>
<tr>
<td>1%</td>
<td>10.2</td>
<td>9.6</td>
<td>9.1</td>
<td>8.6</td>
<td>8.2</td>
</tr>
<tr>
<td>2%</td>
<td>11.3</td>
<td>10.7</td>
<td>10.2</td>
<td>9.6</td>
<td>9.1</td>
</tr>
<tr>
<td>3%</td>
<td>12.6</td>
<td>11.9</td>
<td>11.3</td>
<td>10.7</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Upside Case: 12.4 MM units P.A. by 2027

<table>
<thead>
<tr>
<th>MPG</th>
<th>0</th>
<th>0.5%</th>
<th>1.0%</th>
<th>1.5%</th>
<th>2.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMT-1%</td>
<td>7.5</td>
<td>7.1</td>
<td>6.7</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>0%</td>
<td>8.4</td>
<td>7.9</td>
<td>7.5</td>
<td>7.1</td>
<td>6.7</td>
</tr>
<tr>
<td>1%</td>
<td>9.3</td>
<td>8.8</td>
<td>8.4</td>
<td>7.9</td>
<td>7.5</td>
</tr>
<tr>
<td>2%</td>
<td>10.4</td>
<td>9.8</td>
<td>9.3</td>
<td>8.8</td>
<td>8.4</td>
</tr>
<tr>
<td>3%</td>
<td>11.6</td>
<td>10.9</td>
<td>10.4</td>
<td>9.8</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Source: TPH Research
Declining VMT and Increasing Fuel Efficiency are Not Threats

VMTs showed steady growth with exception of 2008-2014 (recession and high gasoline prices)
Consumer behavior has resulted in slow fleet efficiency gains

Vehicle Miles Travelled (Forecast)

Consumer Behavior Resulted in Slow Efficiency Gains

Source: TPH Research
Electric Vehicles Are Not a Medium-Term Threat to Demand

Plug-in electric vehicles ("PEVs") could be impactful, if the US light vehicle fleet was swapped in its entirety for PEVs tomorrow:
- U.S. oil demand would decrease by nearly 50% from 19.6MMbpd to 10.2MMbpd
- Electricity demand would increase by 25% from 4,100TWh to 5,200TWh (if all incremental power from high efficiency gas plants)
- Natural gas demand would increase by 27% (to fuel incremental power generation) from 75Bcfd to 95Bcfd

However, PEVs do not pose a threat to transport fuel demand in the next 10 years
- PEV’s share of existing fleet is currently a miniscule 0.2%
- To grow to a meaningful portion of the total fleet requires dramatic and consistent annual sales gains along with decades of existing fleet attrition, consumer behavioral change, and significant infrastructure buildout

Increasing fuel efficiency and/or declining vehicle miles traveled ("VMT") are more meaningful threats to mid-term gasoline demand, but neither is likely with low gasoline prices

Source: TPH Research, TPH Asset Management
Potential Impact of Electric Vehicles is Minimal

**Base Case: PEV Adoption 2MM units annually by 2027**

- PEV sales increase 13x over the next 10 yrs to 2MM/yr in 2027 from 150k in 2016
- Results in PEVs holding <3.5% total light vehicle fleet market share

**Upside Case: Still Only 12% Market Share**

- PEV sales increase 50% each of the next 10 years growing to 12.5MM/yr in 2027 from 2016’s 150k
- 2027 Annual PEV sales represent ~65% of all units sold
- Results in PEVs holding <12% total light vehicle fleet market share

Source: TPH Research
Potential Impact of Electric Vehicles is Minimal

Over the next 10 years, average fleet fuel economy and VMT are more important variables than market share

2027 Gasoline Demand Sensitivities, MMbpd

<table>
<thead>
<tr>
<th>Base Case: 2 MM units P.A. by 2027</th>
</tr>
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<tbody>
<tr>
<td>MPG</td>
</tr>
<tr>
<td>-1% 0 0.5% 1.0% 1.5% 2.0%</td>
</tr>
<tr>
<td>0% 8.2 7.7 7.3 6.9 6.6</td>
</tr>
<tr>
<td>1% 9.1 8.6 8.2 7.7 7.3</td>
</tr>
<tr>
<td>2% 10.2 9.6 9.1 8.6 8.2</td>
</tr>
<tr>
<td>3% 11.3 10.7 10.2 9.6 9.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Upside Case: 12.4 MM units P.A. by 2027</th>
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<td>-1% 0 0.5% 1.0% 1.5% 2.0%</td>
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<td>3% 11.6 10.9 10.4 9.8 9.3</td>
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</table>

<table>
<thead>
<tr>
<th>Downside Case: Peak 200,000 units P.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPG</td>
</tr>
<tr>
<td>-1% 0 0.5% 1.0% 1.5% 2.0%</td>
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<td>0% 8.4 7.9 7.5 7.1 6.7</td>
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</tr>
<tr>
<td>3% 13.0 12.3 11.6 11.0 10.4</td>
</tr>
</tbody>
</table>

- 2016 U.S. gasoline demand 9.4 MMbpd
- 2027 outlook for various scenarios
- Fleet MPG and VMT are more sensitive than PEV penetration by 2027

Source: TPH Research
Cross-Firm Technology Expertise

TPH Energy Tech effort is complimented and supported by the cross-firm technology practice of PWP

### PWP Technology Team

**Stefan Green, Partner & Head of Technology**
- **M&A Experience:**
  - NTT DoCoMo on $9.8Bn investment in AT&T
  - CISCO on $1.1Bn investment in Softbank
  - Seagate on its $694MM acquisition of Dot Hill Systems
- 19+ years at Goldman Sachs
- BA, Queen’s College - University of Oxford
- MBA, INSEAD

**Rick Sherlund, Partner & Head of Software**
- 30+ years of investment research and investment banking experience in software industry
- Former Chairman of Software Investment Banking at Barclays
- 25+ years at Goldman Sachs where he was Partner and Head of Technology Research Group
- Former Head of Technology Research Team and Senior Software Analyst at Nomura
- Licensed CPA in State of California
- BS and MBA, Cornell University

**Jackie Chan, Managing Director, Technology**
- Strategic and financial advice to clients in the Technology and Business Services sectors
- **M&A Experience:**
  - PayPal on acquisition of TIO Networks
  - Google on issuance of Class C non-voting stock
  - Oracle on acquisition of Pillar Data Systems
- MBA at Greenhill & Co.
- BS and BA, University of California, Berkeley
- MBA, Columbia Business School

### Selected Technology Deals

#### VMware
- **Undisclosed**
- Various undisclosed engagements
- Completed 2017

#### PayPal
- **$238,000,000**
- Served as exclusive financial advisor to PayPal on its $238M acquisition of TIO Networks
- July 2017

#### Xirrus
- **Undisclosed**
- Sole advisor to Xirrus in connection with its sale to Riverbed
- April 2017

#### AT&T
- **$108,700,000,000**
- Served as lead advisor to AT&T on its acquisition of Time Warner
- October 2016

#### Seagate
- **$694,000,000**
- Acquisition of Dot Hill
- August 2016

#### Alphabet / Google
- **Undisclosed**
- Advisor to the Audit Committee of the Board of Directors on a confidential assignment
- October 2015

The above listed companies are shown for illustrative purposes only. There is no assurance that PWP will have access to similar mandates in the future.