

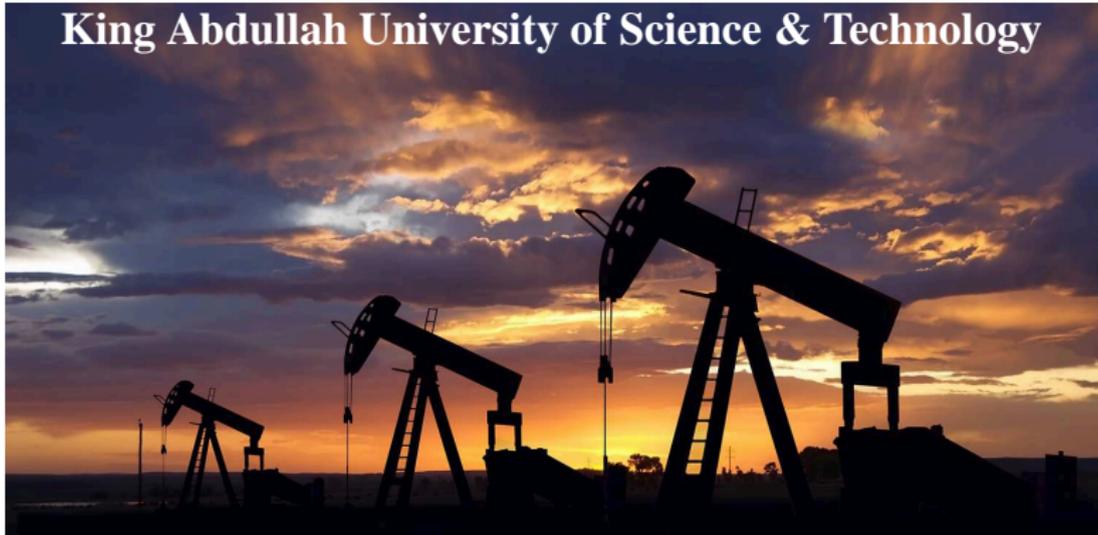
Role of academia in the advancement of upstream oil and gas technologies

2017 SPE-KSA ATSE, Dhahran, Saudi Arabia

Executive Panel, April 25 2017, 13:00 – 15:00 a.m.

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The Context of Academic Research in E&P...

- Crude oil and natural gas are the two most important sources of **power** that builds and maintains modern societies
- Quality of the resource base + extensive social claims on oil&gas production provide the **real floor** on their sustainable price, while health of the global economy provides the **real ceiling**
- All oil companies operate and conduct research between the **market floor** and ceiling prices of the day
- Today's **market ceiling price** seems to be almost exactly **\$55** per barrel, close to the **real floor price** for the remaining resources in most places
- Without **smart** investment and focused research, the oil industry will **crumple** taking the global economy with it
- Academia **educates** the future leaders and **slowly pushes** the envelopes of science and technology

What are the causes of current difficulties?

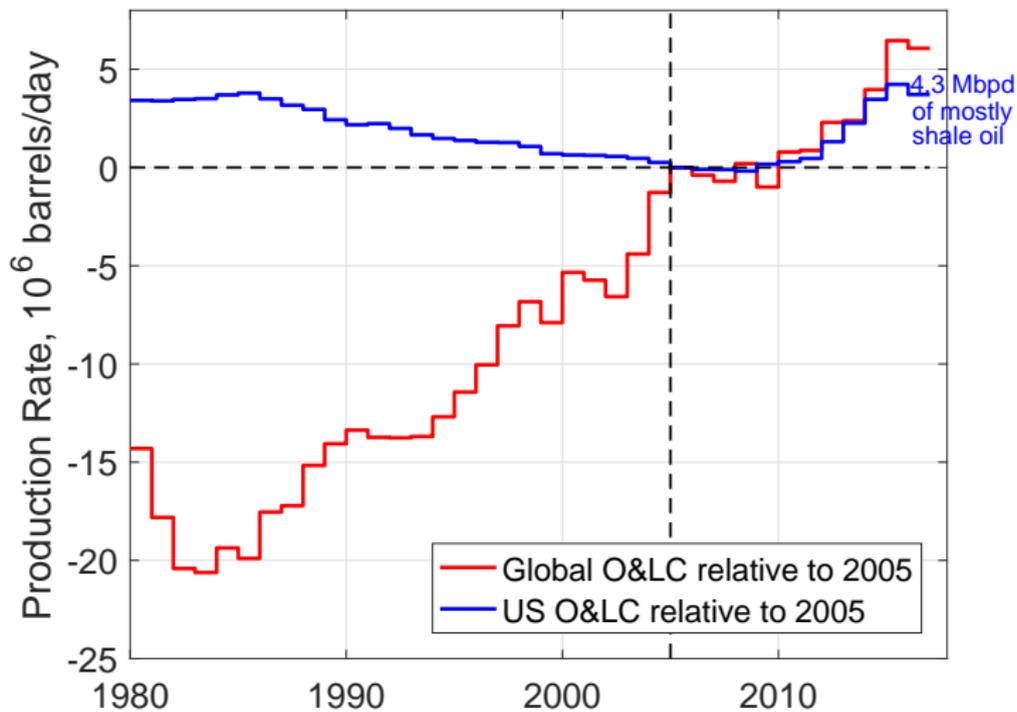
The head of Saudi Arabia's state energy giant has warned of a looming oil shortage as a \$1tn drop in investments into future production takes effect. Amin Nasser, chief executive of Saudi Aramco, the world's largest oil producing company, said on Friday that 20m barrels a day in future production capacity was required to meet demand growth and offset natural field declines in the coming years.

“That is a lot of production capacity, and the investments we now see coming back – which are mostly smaller and shorter term – are not going to be enough to get us there,” he said at the Columbia University Energy Summit in New York.

Saudi Aramco chief warns of looming oil shortage, Anjali Raval and Ed Crooks in New York, FT.

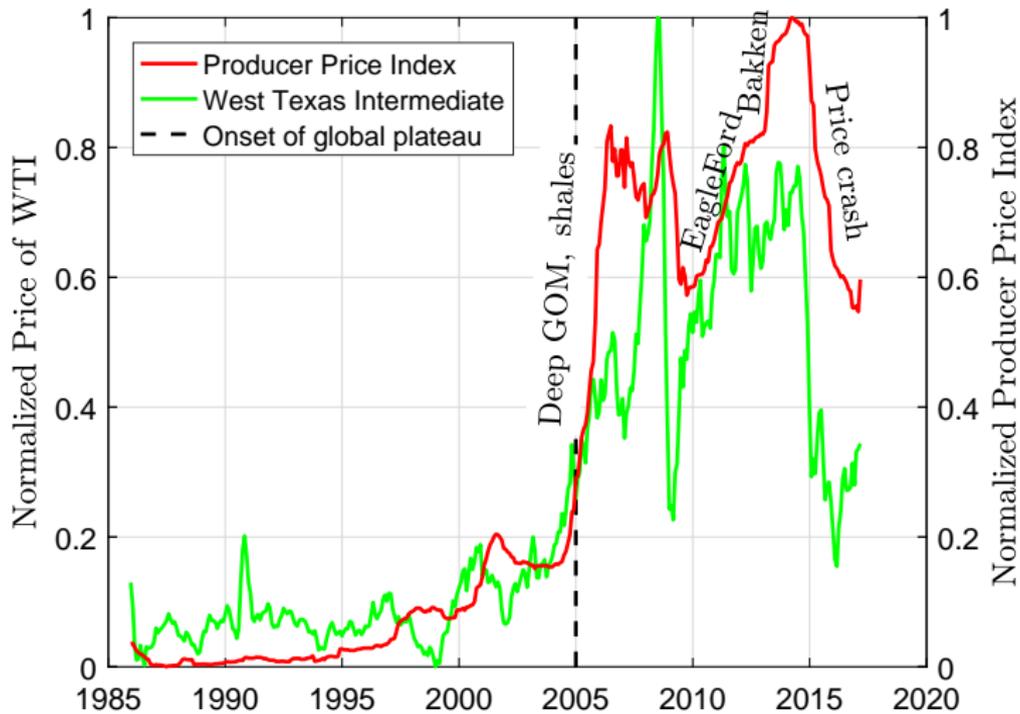
Net Increase of World's Oil & Lease Condensate Production

Relative to 2005. Source: U.S. DOE EIA, accessed 01/18/2017



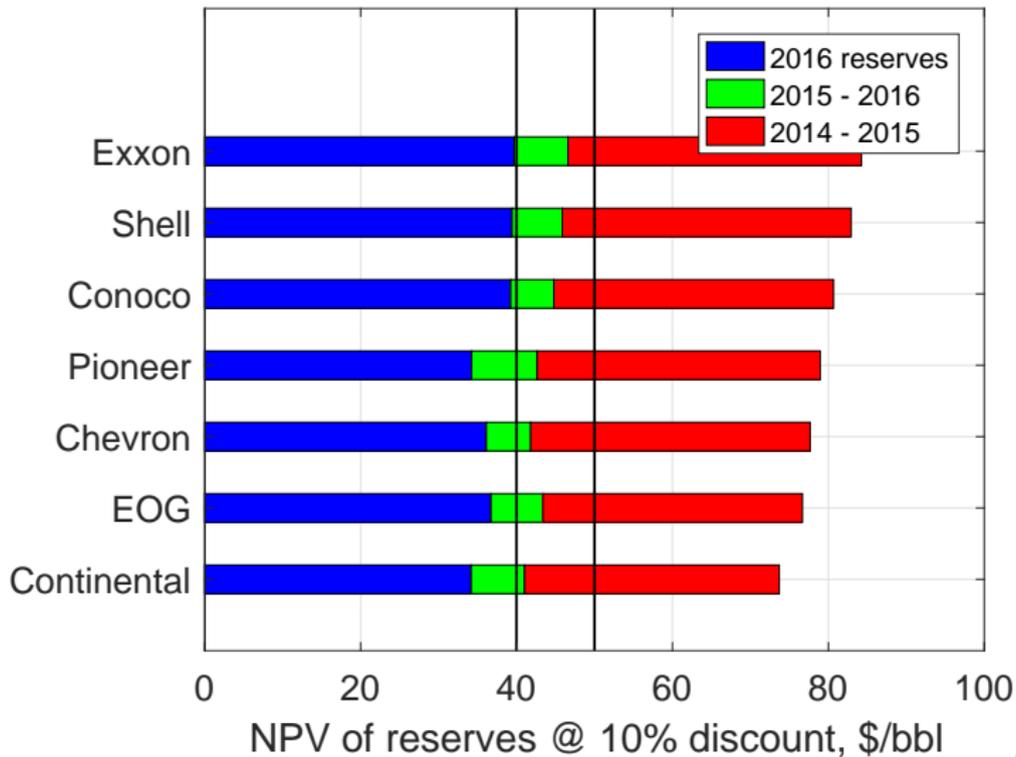
Normalized Producer's Price Index and Oil Price

Sources: U.S. Federal Reserve Bank, EIA, Labyrinth Consulting Services, accessed 04/01/2017



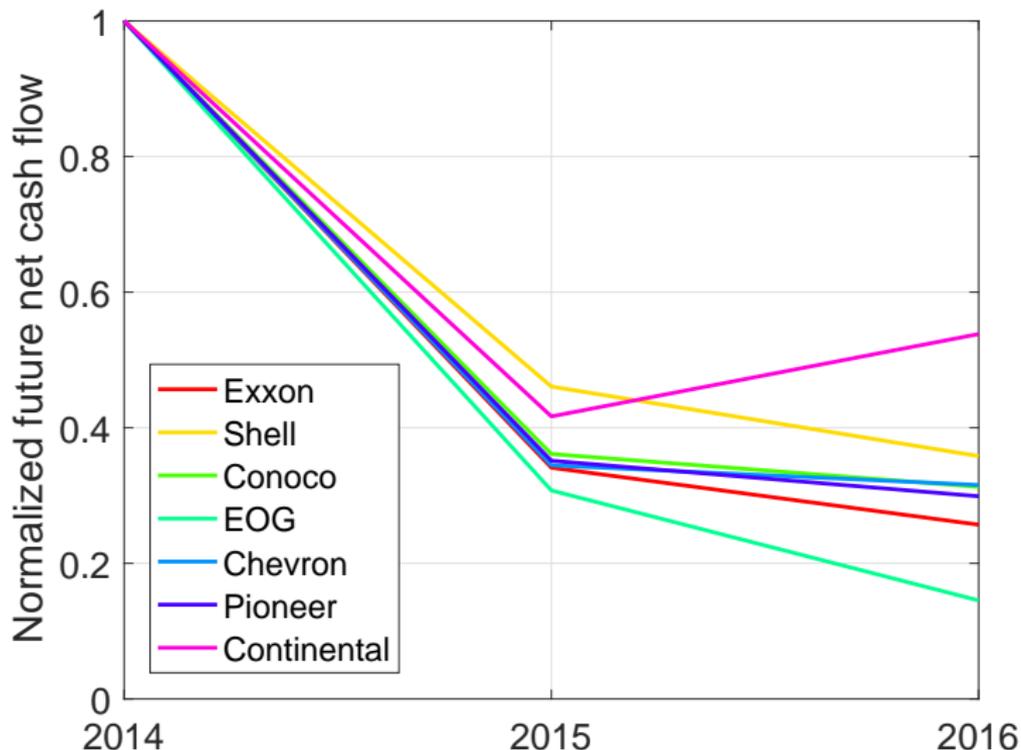
Net Present Value Discounted @10% of Reserves

Sources: 10-K and 20-F SEC filings, Labyrinth Consulting Serv., accessed 04/01/17



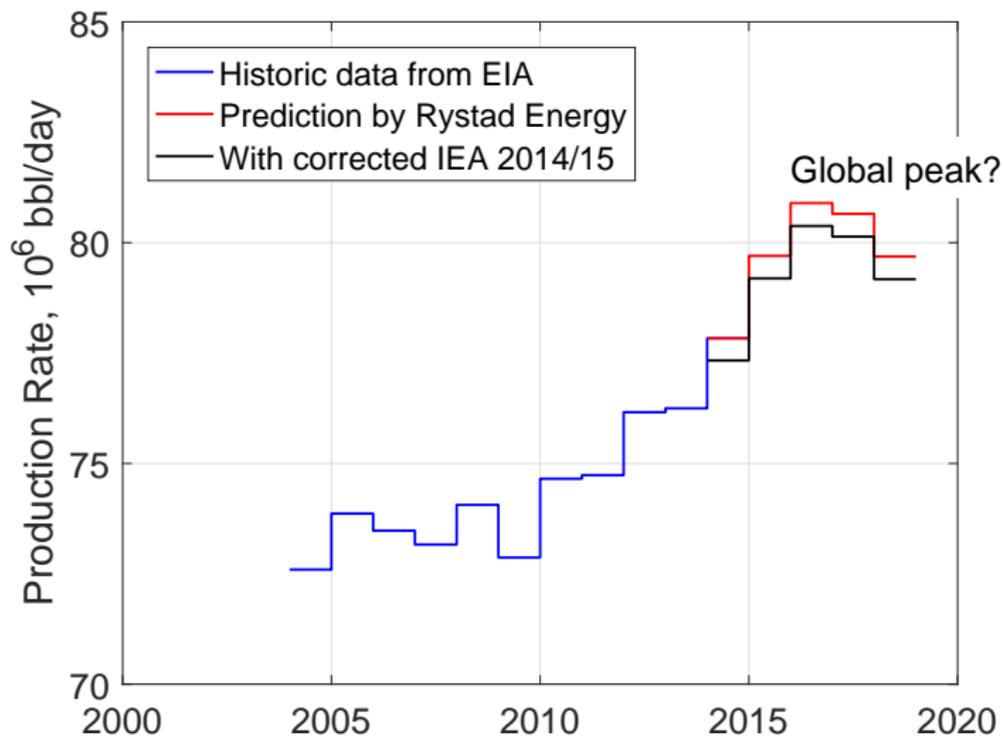
Normalized Measure of Discounted Future net Cash Flows

Sources: 10-K and 20-F SEC Filings, Labyrinth Consulting Serv., accessed 04/01/17



World's Oil & Lease Condensate Production

Is declining. Source: U.S. DOE EIA, accessed 02/01/2016; Bloomberg, accessed 03/23/2016

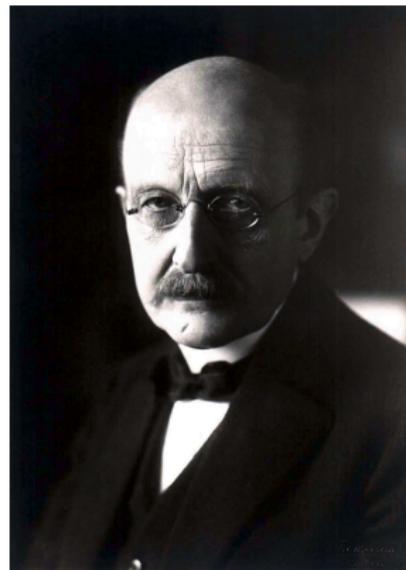


Industry vs. Academia

- Industrial research by its nature is high-rate and **holistic** (you cannot drill 1/2 of a well, or half-instrument it)
- Academic research is high-complexity and **integrative** (new models, new understanding, new connections are developed)
- Academic research should be **collaborative** and can be partitioned into **small** parts to assemble a big picture
- Partitioning **slows** down research considerably and since big discoveries are **disruptive** not cumulative, it may delay big discoveries even more
- **Planck's Principle** holds: With every discovery in science the **difficulty** of the task **increases**

Progress in Science is Difficult

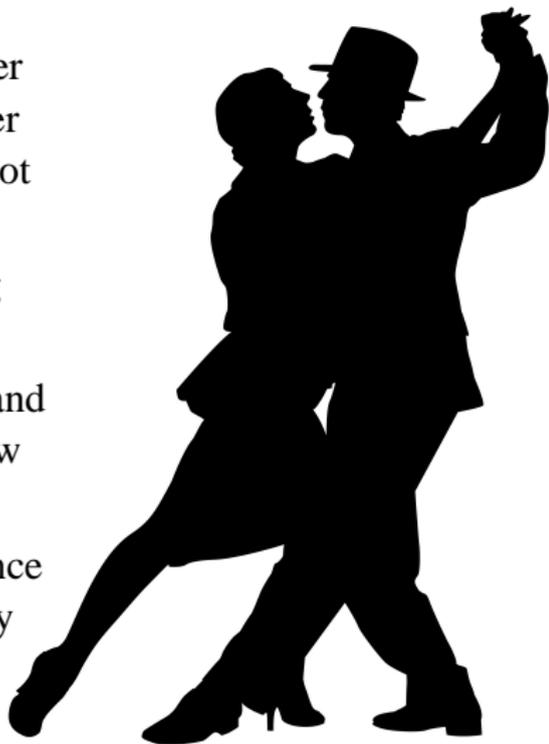
- Ever larger demands are made of **achievements** of researchers
- The need for a suitable **division of labor** (collaboration) becomes ever-more pressing
- Ever fewer researchers can perform fluently the difficult tasks, thus manpower cost and **availability** becomes the limiting factor
- By an absolute standard of importance there is a marked and continuous **increase** of the overall **cost** of research
- The cost increases not because better science is done, but because with time it is **harder** to achieve the **same** level of science



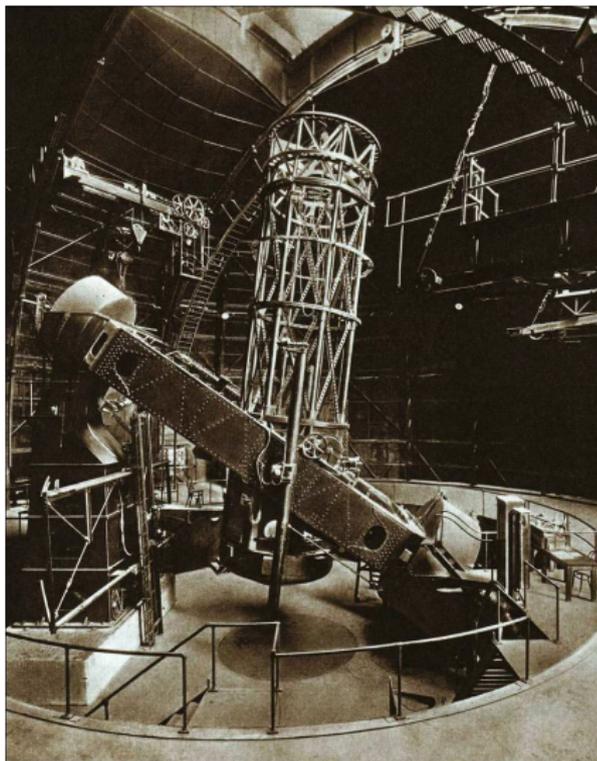
Max Karl Ernst Ludwig Planck, 1858 - 1947

Science and Technology

- Without **new** types of data of ever higher **resolution**, acquired with devices of ever increasing **power**, modern science cannot function
- Technology provides the data gathering **capability** for science
- Science in return provides **new** theory and methods to design and construct the new sensors and machines
- At any given moment, progress of science can occur only **within** the barriers set by the available technology



Science Can Go no Farther than Technology Permits



What if Galileo (1610) had the 100-inch Mount Wilson telescope (1918)?

Final remarks

This is where business planning of research resources should go

When times are tough, **old** solutions are tried **again** and again with **disastrous** results. **What's in store?**

- Modified project management; start small, learn, and scale up
- Better wells
- Infill wells and pattern drives
- Better surveillance with novel sensors
- High-resolution reservoir imaging to place additional wells
- IOR and, in some places, EOR
- Hydrocarbons from unconventional/harsh places

Once there is an overall plan of action, academic research will play an important role in answering some of the fundamental questions and training the new crew