Technip's Technology Day
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Shale Gas and Ethylene: Implications of Increased NGL Production
Claire Cagnolatti, Vice-President of Chemical Studies, Solomon Associates

Moderator

It's my pleasure to introduce our next speaker. She's from Solomon Associates in Dallas Texas, a performance, improvement, consulting firm providing benchmarking services and performance improvement solutions to companies in more than 70 countries in the refining, chemical, power generation and pipeline terminal industries. She brings a wealth of knowledge and experience to the industry, including a BS in chemical engineering, and an MBA from Louisiana State University in Baton Rouge. 14 years of chemical manufacturing, four which were spent in economic optimization, and 19 years at Solomon. Since 2003, she has managed the olefin studies, increasing study participation to over 120 plants. Here we are talking about shale gas and ethylene. Please extend a warm welcome to Solomon and Associate's Vice-president of chemical studies: Claire Cagnolatti.

Claire Cagnolatti, Vice-President of Chemical Studies, Solomon Associates

Thank you. I would like to thank Technip for inviting Solomon to participate today. I would like to thank all of you in the audience who are big supporters of our Olefin study. I can't stand here today and talk about anything without your data. You are the ones that make the Olefin study have value and allow me to make such a presentation. This will be a bit different than most Solomon presentations that you have seen because until recently we weren't involved much with any production. We kind of went from refining downstream with our benchmarking and consulting services, but we recently acquired a company named Ziff Energy. I will talk about that in a minute, but it enabled us to get some insights into what is going on with gas production, LNGs and alike. We sort of brainstormed: what are all the variables involved in deciding how much shale gas are going to be produced from all this wealth that we have in North America. We listed some of the driving forces here, the things that are positive about all this new shale gas, the things that are going to drive toward more production, things like the location being more convenient to the end-users, enforcing North America's energy independence. The ethane economics has just brilliantly showed that big gap in margin where you see the big advantages in North America due to the economics of ethane to make ethylene.
Other things: jobs that will bring the positive shift in the trade balance if we import less foreign energy and we can use this domestic energy produced here in North America. It will help energy intensive industry see a boom as others have talked about in methanol, in ammonia, in petrochemicals such as ethylene. All these

positive things are elevating or increasing the probability that we will see more and more gas production, but there are also, on the flip side, some things that are things detractors might use to try to temper that huge growth or some objections, subparts to the industry, or the communities might have. Some of those things will discourage energy efficiency in North America because energy is going to be cheap like it was in the 1970's. That's true, but there are other positives like converting to natural gas from coal in the power industry, has reduced emissions by about half, so there are environmental benefits. Then, also, is this a renewable resource? No, it's a hydrocarbon sort of traditional hydrocarbon source. You will have to build some pipelines to get it were it is needed, and yes, that is going to be an income but the infrastructure will be using this fuel, this wonderful new gas, whether it is compressed natural gas or LPGs for , say, vehicle use that conversion will take time. But there are some other positive things going on there were things like buses and cabs that can be fuelled as a central location. They have already made the switch in many cities sand municipalities. So, you have those opposing forces, pros and cons. We'll talk about some of those as I go along, then we will take a look at the end, which ones we think are stronger, the ones that are going to influence, whether or not this gas will get produced.

I mentioned briefly Ziff. Solomon recently acquired a company named Ziff Energy, out of Calgary, Canada. They benchmark and study the upstream, the exploration and production of both oil and gas. They have a VP of Gas Production who handles all of their benchmarking studies. They already saw his name on the title slide: his name is Bill Gwozd. He provided a lot of this information. Solomon has access to some of this inside information. For me it was of great interest because this is the feed stocks that my Olefin study clients are looking at and considering, and so understanding more about this was I thought a good thing. They right now do international exploration and production benchmarking and consulting, and North America, the focus on their natural gas forecasting and consulting of course is here in North America. This combination of Ziff and Solomon creates the number 1 benchmarking service provider from the wellhead, all the way to specialty chemicals. So it makes this a more integrated company, and hopefully in this presentation I will combine a little bit of Ziff's knowledge that I learned, and some information from the Solomon's actual ethylene plant data from our study, to give us a better understanding of this dynamic. This is just a brief slide showing you what Ziff does: they do benchmarking and all these different wells. Right now they are concentrated in Canada, they will be soliciting benchmarking studies for gas production in North America, but they look at everything, from the production to the exports, to all the different forces that will affect those production levels.

Wet gas versus dry gas

You heard Jorge from Bain talk a lot about wet gas. What happened? How come all this wet gas came up so quickly? If we look at the added value that wet gas has over just dry gas: mainly shale gas wells early on were not expected to produce as much of the NGLs, or to be as wet as originally predicted. They had a lot more. In fact, without that they are considered dry gas. We'll make a comparison of dry gas and wet gas, and how wet gas adds to the value of the production from the well. There is an increased cost to do separation of the dry gas and the wet, to re-separate the methane from the other component, but that is more than offset by the additional revenue. We'll see that in a moment. In some cases, the ability to sell these liquids is a constraint to producing more gas because you have to find a home for the ethane, propane, butane and other liquids that convince off the well. In some areas that is

going to be a limit on the ability to produce the natural gas. Wet gas wells in shortcut produce more feedstock for ethylene crackers and most of that is ethane. Which wells have more NGLs? My colleague at Ziff was able to provide a map of US and Canada NGL content of wells. You see that the darker the color, the higher the amount of wet gas. You can see the lower amount in South Texas, the Palo Duro in the Texas pin handle, Marcellus, and several others all through the Midwest: Williston, DJ and Arco premium, Fort Worth. All of these have relatively high levels of liquids that come out, so compared to traditional dry gas which you would find a lot of offshore, they have a low to medium amount of liquid. These other areas have high amounts of liquid. This for example is why Shell is building a cracker in western Pennsylvania, because there are natural gas liquids there to feed that plant.

How do the revenues from NGL add to gas wells? We have a graphic that illustrates that if the value of the gas itself is set at one, one of the multiples above 1 that you receive for all the NGLs… this is based on some assumptions of the average natural gas liquids price at about $60 per barrel which is not too far from what ethane price has been for the last couple of years. Then make some other assumptions about royalties and shrinkage. You have to use some of the gas as energy in the processing plant of the well to do the separation, but it's about a 70% markup. So if all gases value 1 wet gas with about 65 barrels per cubic foot, has about 1.7. That's quite a big increase, and that's taking into effect the cost and all the others. So a big boost in revenue for the driller. As the liquid content increases, the multiples of dry gas value also increase. If the best cases, dry gas at 1, depending on the liquid yield from 20 to 100 per MMscfd, you can see that at 100 barrels per MMscfd, you get 2.6 tons the revenue as you do from dry gas. This is the added value of producing and selling these NGLs.

How does all this relate to what the Solomon study said? Our most recent study that has been completed was for operating year 2011. We like looking at a group of plants that have been in three consecutive studies. We call that our trend group. North America was the range with the biggest feedstock change, so I'll focus on North America. This Olefin study trend group is a trend of North American plants that were in three consecutive studies: 2007, 2009, 2011. It represents about 50% of North American ethylene's capacity, so it's very representative. This allows us to see trends on the same plant basis without the population changing. Also, North America has more feed-flexible plants. They have more built-in feed-flexibility than plants in any other region of the world. We will see that coming up shortly. Some plants are making permanent changes. The feedstock flexibility they had to go from light to liquid is now in a lot of cases shifting all the way over to light; they are keeping very little or none of that liquid's cracking capacity. That's going to take some investment and take some time. What we have seen in the short-term is that every North American plant that could, that had the ability to shift to light feed did so very quickly. They took advantage of that ethane economics as soon as the price of ethane started to drop, they made those feedstock shifts to take advantage of that.
Here is the trend I was talking about: 2007. You can see that roughly a 1/3, a little more than 35% of the feedstock in North America was ethane in the dark blue, the sole of ethane and propane light blue and dark blue was at about 2/3. In 2009, that is when that quick shift happened. Roughly 10 percentage points of feedstock shifted from naphtha to ethane. Naphtha was dropped and ethane was picked up. That was the built-in feedstock flexibility that could easily be switched, didn't require much reconfiguration of the plant or a lot of capitals, some minor things maybe had to be done, but that was a quick response. The plants were able to add 10 percentage

points to the ethane as a percent of the total. You can see it maintained for 2011. There was no change from 2009 to 2011. Does that mean we're done in North America? No, that was just the short-term. The immediate, we can switch to Athena now. Let's do it with some minor modifications. Other feedstock changes are going to take longer. What we estimate is that we may not even see it in the current study for operating year 2013 which will be getting results of that in July of next year, but not maybe until 2015 when we see some projects that have been completed for changing feedstock's in existing plants, and bringing new ethane feed plants on line.

As mentioned before by Mark, what happened to the Co-product Propylene and butadiene? Of course, as you switch to more ethane feed, you make less propylene and much less butadiene. North America had a severe shortage of propylene and butadiene, and so prices rose worldwide. The prices for butadiene and propylene in 2011 were exhorbitant, multiples of ethylene price. We don't see that very often. Ethylene is usually the dominant, sometimes propylene will sometimes fluctuate a little bit over ethylene, based on the demand for durable versus non-durable goods. In 2011 the prices soared. Now they have tempered a little: higher prices did make the non-cracker base production, or the alternative production economics look a bit better. We are going to look at what we can do about that in terms of on-purpose propylene and butadiene. We did see some propylene shortages, but they were short term and prices moderated once some alternative production came into being.

Here is some types of alternative production. Refineries normally make refinery grade propylene, but if they can move the mercury in the arsine and put them through a C3 splitter, maybe a cracker nearby that shift it to light feed, has a c3 splitter that is not doing a whole lot. Maybe you could shift some of the refinery propylene to the cracker that can then separate it and create polymer-grade propylene or refineries as we saw in presentations earlier this morning: you can shift the primers of the FCC such that propylene yields coming out of the DCC are higher. That can justify refineries building their own C3 splitters. You can also have propane from propylene from propane dehydrogenation (PDH). There are eight PDH units that were announced to be built in the US so far. But these, the economics of PDH could really tan on exports plans. We have heard several people talk about the fact that yes there will be an excess depending on how fast the demand increases in North America. So propane will be available for export. How fast that happens? We'll probably have a determining effect on whether propane prices go too high and make PDH an economical or not. All of that is going to be predicated on all those different variables that are being juggled. PDH is also being pursued in the middle-east, in Eastern Europe and in Asia. We will see more propylene from PDH. There are other on-purpose propylene. In fact catalytic conversion of butadiene and ethylene to propylene, also known as metathesis, has become popular enough that we actually added it to our Olefin study in 2009. We are not collecting data on this on-purpose. Propylene is part of the overall Olefin study. We're considering adding propane dehydrogenation as well, as another wrap to olefins that will include in our benchmarking studies. Not so many alternatives for butadiene. You can make butadiene the metathesis, but it is not as tried and tested in the marketplace as On-purpose. Propylene is. You can have butane dehydrogenation but again, its economics are going to depend on economics of butane and butane has seasonal characteristics were it can be blended into gasoline during winter months but not in summer months because of RVP requirements. Butane is a little bit icy. You can get butadiene from biomass but so far those have not produced large volumes. Those processes have not produced large volumes of butadiene. Economic feasibility of this

On-Purpose production is supplement to what was lost in the feast up-shift to ethane and propane. All of this depends on the product price, relatives to the raw material cost, investment costs and of course exports will have a lot to do with how the raw material cost will iron out over time.

What about the rest? The other uses?
Transportation: I was surprised a couple of years ago to find out that all the Dallas buses had converted (I'm from Dallas) to propane. I was on the freeway in Dallas a few days ago and I saw taxicab with a sign on his trunk that he had converted to propane fuel. When you have fleet vehicles like that, that are refilled in a central location where you can just buy the propane tank and put it there, it makes sense. But in order for that to trickle down to you and me taking our car to the service station and filing it full of propane, there has got to be a lot of infrastructure built and that's going to be a slower transition. These fleet vehicle conversions will take place because it is more convenient for central refueling. All the projects that have come out about exports to Europe - you've heard some of the other gentlemen this morning talking about all the different projects and exports, and people trying to secure supply and use it for cracking or use it for dehydrogenation. The LNG is for fuel or for conversion to liquids and others (methanol). LPGs can be either cracker feedstock or for transportation fuel. We also looked at SYNGAS and gas-to-liquids. There is a project here in the US for that, there are projects in other parts of the world. There is a lot of different end-uses competing for those molecules that come out of shale gas. Power generation has soaked up a good bit of the additional natural gas produced and it has displaced coal which has cut the emissions of power generation in half. When you convert a coal fire power plant to natural gas, you cut the green-house emissions in half. That's popular with the environmentalists and developers, maybe not so popular with coal miners but it is happening in the United States to a great extent. The price for LPGs and other swill depend on a lot of these things: logistics, how quickly all these other uses come into practice, all the different things we looked at with the arrows pushing up and the arrows pushing down. All of these different things happening. Some will be stronger than others at times. You have all these things being juggled. I think about the eight scenarios that Jorge presented. Imagine if you were juggling all of those at one time. That is kind of what you have to do to think about all the possibilities and all the things that are going to influence the final market position.

How much shale gas is out there?
An optimistic view says we have 100+ years. Sounds great but are we going to be able to produce it economically because, is the price of natural gas going to support all this activity? Are we going to overproduce such that the price of natural gas falls too low? That has kind of happened already. In some places, as I mentioned, the limit to North America natural gas production is disposal of the ethane and propane but it is also the price. The low price may cause a decline in the amount produced. If you can't get as much money as you did for natural gas, if it keeps getting cheaper, then you may not want to mine or produce as much.
Up to eight new ethane crackers coming on line between now and say the next three-four years. As that ethane gets consumed, it will create more room to produce the natural gas with the ethane. It could lead also to lower prices. All these forces at work, take very complicated models to understand all the possibilities. There is also some shale gas in the middle-east, in South America, in China and Eastern Europe, Australia, but they have not explored it to the extent that we have so far here in North America. From the beginning, we talked about these positive and negative forces.

Let's see which forces are stronger. Right now we're producing quite a bit of the shale gas so we have to say the ones in bold, the large amount reserves, reducing emissions, both by displacing things like diesel and coal, being a competitive cracker feed, has supported production, the location of the ones especially close to the golf coast where the cracker feeds are needed, ethane economics, energy independence as a big idea, available capital. There is evidently a lot of capital available to invest in these projects. Even though the oil industry or the gas industry, when they first started, probably not as careful as they should have been with the environment _ I understand there is some ground water contamination and things, but I think they have cleaned up their cat and they are doing a great PR campaign, advertising. The jobs is going to be the biggest. The jobs created, the resurgence in North America's economy. The boost to the economy. These are the positive things that are supporting the production of more natural gas. The ones that I have put at the top, in italics, are the ones that can be mitigated. You can mitigate the glut of LPGs by rationing or managing the amount produced. You can manage less co-products by doing more On-Purpose. Pipelines are needed but there is capital to build the pipelines, etc. Based on the things we can address, the other routes, that supports the production of more of this shame gas.
I look forward for your questions at break. Thank you Technip for the opportunity to speak today.