FINAL Minutes of December 9, 2021 Ethylene Producers' Environmental Sub-Committee Meeting
(December 9, Rev. 0)

Following are the minutes of the December 9, 2021 Ethylene Producers' Environmental Sub-Committee Meeting, held in-person and via MS Teams with Mark Ulrich, Linde and Walter Postula, Shell Global Solutions (US) Inc., as hosts. Thank you, Mark and Linde for hosting!

Present: Troy Boley, Spectrum Environmental Solutions, LLC [MS Teams]
Jacob Hilbrich, Chevron Phillips [MS Teams]
James Kendall, ExxonMobil Chemicals [MS Teams]
Brandon Lithgoe, Ashworth Leininger Group [In-person]
Dan Lutz, Ineos [MS Teams]
Jennifer Port, ExxonMobil Chemicals [In-person]
Walter Postula, Shell Global Solutions (US) Inc. [In-person]
Gerardo Ruiz-Mercado, US EPA (AIChE Environmental Division) [MS Teams]
Jason Trembly, Ohio University (AIChE Environmental Division) [MS Teams]
Mark Ulrich, Linde Engineering Americas [In-person]
Gary Wojnowski, BASF [MS Teams]

Absent: Rick Beleutz, LyondellBasell
Benjamin Burns, LyondellBasell?
Ahmad Hamad, Siemens-Energy
Ted Heron, The Catalyst Group
Allyson Ledet, NOVA Chemicals
Patti Long, Eastman
Andrés Muñoz Gandarillas, Neste
Arijit Pakrasi, Edge Engineering and Science
Mark Schmidt, Dow
Jeffrey Seay, University of Kentucky (AIChE Environmental Division)
Edward Soliz Jr., LyondellBasell

The meeting began at 10:03am with Walter Postula reading the Ethylene Producers' Committee (EPC) anti-trust statement:

> No activity of the committee shall involve the exchange, collection, or dissemination of information among competitors for the purpose of bringing about or attempting to bring about an understanding or agreement, written or oral, formal or informal, express or implied, among competitors, with regard to costs, prices, pricing methods, terms or conditions of sale, distribution, production quotas or other limitations on either the timing or volume of production or sales, or allocation of territories or customers.

The meeting agenda was published in advance and is included below:

1) Reading of Anti-Trust Statement [10:02 AM]
2) Review, accept/reject, and ordering of session papers (titles below, abstracts attached) [10:05 AM]
   - *Cracking of Renewable Feedstock*; M. Jordens and R. Reguillo
   - *Shell and the Plastic Circular Economy: Innovation, Collaboration and Investment*; L.A. Grau Sr. and N. Genty

- *Combined Experimental and Kinetic Modeling Study of Thermal Decomposition of DEHA: Formation of NO and HCN*; C.A.R. Pappijn, G. Bellos, A. Bojkovic, M.F. Reyniers, J. Aerssens, and K. Van Geem
- *Sustainability Certification for Ethylene Supply Chanins Using ISCC PLUS*; P. Hawighorst
- *Ethylene Risk and Technology Review: What's the Path Forward?*; S. Smith
- *ESG Economics Lead to Third Party Verification of Greenhouse Gas Emissions*; J. LeBlanc and B. Lithgoe

3) Review of Action Items [10:50 AM]
4) Important Date Reminders
   - June 28, 2021 – Call for abstracts opens
   - November 30, 2021 – Call for abstracts closes
   - December 10, 2021 – Papers accepted or rejected
   - January 3, 2022 – Draft Program for Review
   - January 10.2022 – Comments from Chairs Due
   - January 17, 2022 – Final Program Posted
   - January 24, 2022 – Final Acceptance/Rejection letters
   - March ??, 2022 – Paper submission closes
   - April 10-14, 2022 – Spring Meeting – San Antonio, TX
5) Adjourn [11:00 AM]

Welcome to new members: Lack of mention during the meeting was an oversight. Welcome to our new members, James Kendall (ExxonMobil) and Allyson Ledet (NOVA Chemicals).

Review, accept/reject, and ordering of session papers: After reviewing the submitted abstracts (shown in Appendix) it was decided that the abstract from Ghent would be a better fit for Feedstock or Operations (post telecon note: could also fit in Safety). The remaining five abstracts will result in a full session, with the RTR/flaring paper as double length. The following order was settled upon for the session.

(5 min) Welcoming Remarks
(50 min) Ethylene Risk and Technology Review: What's the Path Forward?
(25 min) Cracking of Renewable Feedstock
(20 min) Break
(25 min) Shell and the Plastic Circular Economy: Innovation, Collaboration and Investment
(25 min) Sustainability Certification for Ethylene Supply Chains Using ISCC Plus
(25 min) ESG Economics Lead to Third Party Verification of Greenhouse Gas Emissions
(5 min) Closing Remarks

Troy Boley mentioned that he had communicated with Steve Smith and could assist with the flare monitoring aspect of the presentation if Eric Swisher was not available.

The deadline for final acceptance/rejection and ordering within Confex is December 10th. The tentative date/time for the Environmental session is Wednesday, April 13, 2022 from 8 – 11 AM. Post telecon note: Tentative time for session is confirmed.

Follow-up on Action Items: Action items from October 14th meeting and follow-up are listed below (those completed as noted in the October 14th minutes are not included).

- **Andrés**: Reach out to ISCC again regarding interest in presenting on certification. Keep Jake Hilbrich in loop. Abstract part of session.
- **Andrés**: (Re)Connect with Ghent on their willingness (and topic) to present. Ghent submitted abstract. Better fit in different session.

- **Jake**: Reach out to his ISCC contacts regarding presenting on certification. Keep Andrés in loop. Abstract part of session.
- **Jake**: Inquire about Chevron Phillips intent with potential paper/presentation on plastic circularity. Communicate with Walter about need/desire for two talks. Second paper not needed. Potential for 2023 conference.
- **Brandon**: Check interest of potential authors/presenters (that he has in mind) on Regulatory Landscape for New Feeds and GHG Inventory/Quantification topics. Regulatory impacts pertain to pyrolysis oil producers, not ethylene producers.
- **Andrés**: Follow up with potential for company to present on renewable feedstock processing. Abstract included in session.

Review of Action Items: Below are the action items (responsible in **bold**)

- **Walter**: Add abstract from ALG (Brandon) to Environmental session in Confex (DONE)
- **Andrés/Gerardo**: Finalize session in Confex. (DONE)

Important Date Reminders: The dates listed in item 4 of the agenda were reviewed. The red indicates when dates were changed from previously listed.

Adjourn: The meeting/teleconference was closed at 10:37 am.

Appendix

Cracking of Renewable Feedstock

Marc Jordens and Rebecca Reguillo [Borealis]

ABSTRACT:
Borealis and our commitment with sustainability, is working in ways to offer viable alternatives to conventional feed stocks, which will not only reduce the Borealis' plant's overall CO_2 footprint, but also help our customers maintain high product quality while meeting their own sustainability goals.
Increasing renewable and bio-based feed stocks in our steam cracking facilities in Porvoo, Finland and Stenungsund Sweden as well as our Propane Dehydrogenation Plant in Kallo, Belgium, is the foundation for achieving this goal, both through base chemicals as well as the Bornewables™, the Borealis portfolio of premium circular polyolefins.
On this journey, Borealis has processed second generation renewable feeds at its petrochemical facilities. In this paper, we will describe the way Borealis has set up the process and the results of the tests that have been performed. This paper will focus on the preparations for the tests, including a detailed analysis of the feed, a risk assessment on furnace and recovery section, simulations performed to select the most suitable furnace and specific parameters that were monitored.
During the tests, follow up was done by monitoring these identified meters and analysers. Finally, the tests results were compared to the simulated values.

Shell and the Plastic Circular Economy: Innovation, Collaboration and Investment

Luis A. Grau Sr. and Nicolas Genty [Shell]

ABSTRACT:
Plastic products bring important benefits to society - helping to improve living standards, and deliver health, safety, and sustainability benefits. Customers use it to make products such as medical equipment, furniture and home appliances. Plastic is also integral to the energy transition, for example, in components of solar panels and wind turbines; and building insulation and light-weighting transportation; helping society to lower carbon emissions.
Plastic, however, is often associated with disposable and throwaway packaging; and in places where waste management infrastructure and traditional recycling don't exist, or plastic waste is not managed appropriately, it can end up as litter. Like our customers, we are concerned about the global plastic waste issue. Plastics don't belong in our oceans, rivers or landscapes. To solve this societal challenge industry, governments and customers need to work together.
Annual global plastics production is approximately 367 million tons/yr. It is estimated that of the plastic waste generated, 260 million tonnes, only 16% is recycled, and the remainder goes to landfill, incineration or is unmanaged after use. Plastic recycling rates vary widely by region and are far below the global recycling rates for products like paper (60%) and iron and steel (~80%)[1].

Unlocking the potential of the plastic circular economy
Shell supports the need for improved circularity of global plastics markets - encouraging reduction, reuse and recycling of plastics to mitigate the release of plastic into the environment.
We are playing an active and prominent role through innovation, collaboration and investment to find lasting solutions.
Shell is a leading member of the Alliance to End Plastic Waste. This is an alliance of global companies including chemicals and plastic manufacturers, consumer goods companies and waste management

companies, along with the World Business Council for Sustainable Development. It has committed $1.5 billion over the next five years to projects across four strategic pillars:

- *Infrastructure*: Catalyse investment in enhanced waste infrastructure to prevent plastic from reaching the environment.
- *Innovation*: Innovate new sustainable materials, designs, technologies and business models based on sound science and economics.
- *Education*: Engage and collaborate with governments, industry and consumers to drive effective solutions.
- *Clean-up*: Develop solutions to address and clean up areas of existing plastic waste in the environment.

Shell is responding to customer demands for more chemical products with less virgin-hydrocarbons. We are developing and investing, with industry partners, in advanced chemical recycling. Using a special heating process called pyrolysis, it transforms hard-to-recycle plastic waste, which would otherwise be incinerated or go to landfill, into a liquid feedstock that can be used to produce chemicals. This liquid, referred to as pyrolysis oil, is used in a cracker at a Shell chemicals plant to produce a range of chemicals, including plastics.

Delivering on Shell ambition

Shell has an ambition to recycle one million tonnes of plastic waste in our global chemicals plants by 2025; and we are working with partners at different stages of the value chain to grow the market for pyrolysis oil to industrial and profitable quantities and deliver on our ambition.

In 2019, collaborating with Nexus Fuels, Shell successfully started using pyrolysis oil in our Norco petrochemicals plant in the U.S.; and over the next three years Shell will use 60,000 tonnes of pyrolysis oil from Nexus Fuels at Norco. We are exploring ways to increase these volumes. In Europe, we have also completed successful pyrolysis oil pilots at our facilities and are about to do the same in Asia; and we are investing in pyrolysis technology and securing more supply volumes.

Recently, Shell invested in BlueAlp[2] and together we will work to develop, scale and deploy BlueAlp's plastic waste to chemicals feedstock technology. Already at a commercial scale, Shell's technology experience and size will help BlueAlp to further improve and scale-up the capacity of BlueAlp's technology to recycle larger volumes of plastic waste. BlueAlp's technology will be license to others to support the exposition of pyrolysis oil production globally.

In the Netherlands, Shell and BlueAlp (through a joint-venture company) will build two conversion units with the combined capacity to process approximately 30,000 tonnes of tough-to-recycle plastic waste. The two units are expected to be operational in 2023 and Shell will use 100 percent of the pyrolysis oil at its Moerdijk (The Netherlands) and Rheinland (Germany) plants. Shell is also exploring licensing a further two units for deployment within Asia to supply the Shell Energy and Chemicals Park Singapore.

Additionally, Shell has secured supply for its European crackers from pyrolysis oil producer Pryme. Currently under construction, Pryme's Rotterdam plant is scheduled to be operational in 2022 and is forecast to convert 60,000 tonnes of plastic waste into pyrolysis oil annually.

Inconsistent purity of pyrolysis oil is an industry-wide challenge and one that impedes the growth of the market. Shell plans a first for the industry, with the deployment of its propriety technology to upgrade the purity of pyrolysis oil at Shell assets. With this technology Shell will be able to use pyrolysis oil with a wider range of characteristics, reducing the need for low-grade pyrolysis oil to be re-processed, and improve market's commercial potential.

Our U.S. sites (Norco and Geismar) and plants in Singapore, Germany and The Netherlands have been certified by the ISCC [International Sustainability and Carbon Certification], an independent third party, to produce circular chemical products from pyrolysis oil. While volumes are currently limited, we are looking to grow supply quickly.

After a brief introduction describing the issue at large and Shell's response and ambition, this paper will focus on the collaboration between Shell and BlueAlp to produce pyrolysis oil, the deployment of Shell's propriety technology to upgrade the purity of that pyrolysis oil at Shell assets to make it suitable for

processing in our steam crackers and the cracking of pyrolysis oil in Shell steam crackers in Moerdijk, Rheinland and the Shell Energy and Chemicals Park Singapore. The paper will conclude on the progress made to date and the future developments required to achieve Shell's ambition.

[1] McKinsey: Plastics recycling: Using an economic-feasibility lens to select the next moves
[2] Shell has 21.25 equity stake in BlueAlp

Combined Experimental and Kinetic Modeling Study of Thermal Decomposition of DEHA: Formation of NO and HCN

Cato A.R. Pappijn, Georgios Bellos, Aleksandar Bojkovic, Marie-Françoise Reyniers, Jeroen Aerssens, Kevin Van Geem [Ghent University]

ABSTRACT:
Thermal decomposition of the steam cracking additive diethyl hydroxylamine (DEHA) leads to formation of the small nitrogen-containing compounds HCN and NO, which can have an influence on the process safety. In this contribution the thermal decomposition of DEHA is studied both experimentally and theoretically under typical steam cracking conditions. The experimental investigation is conducted in a 90 cm long annular quartz flow reactor, having outer and inner tube diameters of 2.1 and 1.5 cm respectively. Steam cracking experiments of propane with addition of 1000 ppmw/HC DEHA are performed over a temperature range of 700 – 850 °C at a fixed pressure of 1.5 bara. This enables to investigate the influence of temperature on the distribution of the nitrogen-containing products, as well as the interaction with the propane steam cracking process. The reaction effluent is sampled on-line at 300 °C. The unique on-line sampling system consists of valve-based sampling manifold and uniformly heated transfer lines connected to a comprehensive two-dimensional gas chromatograph (GC × GC) equipped with a flame ionization detector (FID) and a nitrogen chemiluminescence detector (NCD). This set-up allows to detect and quantify both pure (with the FID) and nitrogen-containing compounds (with the NCD) using a fixed flow of 3-chloropyrdine as an internal standard (added to the effluent right after the exit of the reactor before the sampling point). The GC × GC-FID/-NCD settings are optimized for trace analysis of nitrogen-compounds in olefin-rich hydrocarbon matrices produced during steam cracking. There is a complete conversion of the reactive DEHA over the complete temperature range 700 – 850 °C, with HCN as the main nitrogen-containing product. Acetonitrile (CH_3CN), 2-propenenitrile (CH_2CHCN), NO, diethylamine and pyridine are minor nitrogen-containing products. To gain understanding of the underlying decomposition mechanism of DEHA in the presence of a hydrocarbon matrix, a kinetic model is constructed with the in-house automatic kinetic model generation software tool called Genesys. Genesys makes use of user-defined databases containing thermodynamic and kinetic parameters for hydrocarbons and nitrogen-containing compounds calculated with the ab initio CBS-QB3 composite method. If data is not available for certain species or reactions, the group additivity method based on these high-level ab initio calculations is applied. No adjustment of the kinetic parameters to the experimental data is performed. The kinetic model succeeds in capturing the main experimental trends for the decomposition of DEHA in a propane matrix. Rate of production analyses reveal the important pathways for HCN and NO_x formation. Decomposition of DEHA is initiated both via hydrogen abstraction from Cα, i.e. the carbon next to the nitrogen atom, as well as via homolytic scission of the weak N-O bond. A series of hydrogen abstraction and β-scission reactions leads to formation of HCN as the main nitrogen-containing product, which is a stable product species in the studied temperature range.

Sustainability Certification for Ethylene Supply Chains Using Iscc PLUS

Peter Hawighorst [ISCC System GmbH]

ABSTRACT:
Sustainability certification for ethylene supply chains using ISCC PLUS
The circular economy and the bioeconomy continue to grow. Both have the goal of reducing the dependence on virgin, fossil resources and of reducing GHG emissions. Legal framework requirements like climate neutrality targets, recycling quotas, plastic taxes as well as consumer preferences, company commitments and stakeholder pressure are further driving the circular economy and bioeconomy, in North America, Europe as well as in other regions of the world. Along the complex supply chains, chain of custody concepts like mass balancing ensure the credible connection of sustainability information and the respective materials and products. Compliance with these concepts and its verification is crucial to ensure credibility for companies being involved. The International Sustainability and Carbon Certification (ISCC) scheme is increasingly being used by more than 5,000 system users worldwide and across entire supply chains from point of origin of the initial raw material via the petrochemical and chemical industry to converters and brandowners.
ISCC operates different schemes. ISCC EU is recognized by the European Commission as a voluntary certification scheme for the European biofuels market. ISCC CORSIA is recognized by ICAO (International Civil Aviation Organization) being a specialized agency by the United Nations for the aviation sector for the certification of sustainable aviation fuels. ISCC PLUS is a voluntary certification scheme for the circular economy and the bioeconomy being used by many companies in the chemical and downstream industry all the way to final producers.
Ethylene producers worldwide are already using ISCC PLUS certification. ISCC builds up credibility and acceptance for both, B2B partners and consumers and can potentially be used for reporting under regulatory frameworks or voluntary initiatives. The presentation will provide an overview on ISCC and ISCC PLUS, its sustainability and traceability requirements, ways to get certified under ISCC and benefits for ISCC certified companies.

Ethylene Risk and Technology Review: What's the Path Forward?

Steve Smith [Lyondell Basell]

ABSTRACT:
EPA promulgated the Ethylene Risk and Technology Review (RTR) National Emission Standard for Hazardous Air Pollutants (NESHAP, 40 CFR, Part 63, Subpart XX and Subpart YY) on July 6, 2020. It is applicable to new and existing ethylene production units. The final rule included requirements for furnace and decoke operations, flares, process vents, heat exchange systems and pressure relief devices. The final rule eliminated the exemption for startup, shutdown and malfunction operations and requires the emission limits must be met at all times.
This paper will discuss the rules and the potential impact on the ethylene production units.

ESG Economics Lead to Third Party Verification of Greenhouse Gas Emissions

Joel LeBlanc and Brandon Lithgoe; [Ashworth Leininger Group]

ABSTRACT:
ESG – Environmental Social Governance – continues its increasing influence in the business world, especially in manufacturing segments where sustainability issues have a direct correlation to the financial health, risk, and value of the business. The environmental component of ESG is of particular interest to ethylene producers because the traditional method of ethylene production – thermal cracking of hydrocarbons – is an energy intense endothermic reaction whose needs have historically been met

by the combustion of petroleum-based fuel that result in greenhouse gas (GHG) emissions to the environment. Mitigating this environmental impact is of utmost concern to the ethylene producer to satisfy the demands of various stakeholders – investors, insurers, customers, regulators and others. Mitigation can be in many forms but to be successful and have merit the accuracy of emission estimations and reductions is critical. Following the principles of financial accounting and reporting, standards for GHG quantification, verification and certification are quickly evolving. This paper will focus on these developing standards and how they can be applied to the ethylene producer that requires trusted data for important financial decisions.