Subject: FEWtures Advisory Group Newsletter for March 16 2022

Dear Advisory Group members:

As noted in a previous email, we have decided to go forward with newsletters and zoom meetings in the fall (second Thursday in October – October 20, 2022, 2-4 CT) and newsletters in late winter to spring. This is because the February meetings had been smaller, in part because it is during the legislative session in the states involved.

Please contact us anytime you have comments and questions! Your involvement is critical.

Recent Explosion in Ammonia Prices

Our FEWtures project is becoming increasingly relevant as the price of ammonia fertilizer hits new highs. I thought this exchange with Advisory Group members Vance and Louise Ehmke in recent months would be of general interest. It is also exciting to share that Vance and Louise were highlighted in the 2022 Kansas Governor's State of the State address! I lightly edited the text for clarity. Below, Peter refers to this article about Sri Lanka: https://www.nytimes.com/2021/12/07/world/asia/sri-lanka-organic-farming-fertilizer.html

> **Vance:** In case you weren't watching, the prices for anhydrous ammonia have just exploded over the past 6 months. Right now anhydrous ammonia prices at the Garden City Co-op in Dighton KS are $1500/ton. And there is a distinct possibility that this is not the top. For perspective, in 2020, we paid $340/ton; in '21, we paid $640/ton. And, as mentioned, it is now $1500/ton. I have talked to other coop suppliers who say it could go to $1600 to even $2000/ton.
>
> These high fertilizer prices are definitely going to impact how much fertilizer farmers use and, as a consequence, yields of crops and ultimately crop prices. This is also a worldwide problem. In India, for instance, observers are trying to get a handle on how much rice production will suffer because of the shortages and high prices. They fear that even small cutbacks in usage will result in high production shortfalls. Consequently, India may not be able to export any rice this year. China, which is a big exporter of fertilizer, has shut off all exports so they can use it themselves for their own food security. Sure glad we don't farm in Brazil---they have to import 80% of their fertilizers.
>
> **Peter Pfromm:**…there's currently a nation-scale experiment of what happens if an island nation like Sri Lanka has to forgo fertilizers and pesticides due to lack of money.... It's not good. The people of Sri Lanka get the short stick due to COVID induced lack of tourism and therefore no currency = no ammonia/urea since they don't produce their own.

Interestingly, the 40% yield reduction due to no ammonia (urea) cited in the article confirms what I always use as in "what part of our food is due to man made ammonia via the Haber-Bosch process?".

Manure etc. is of course no alternative, also nicely pointed out. Manure is OK for your backyard, not for agriculture at scale. [Mary: see more about this below]

Environmental problems due to over/improper use of fertilizers etc. arise of course also.

[The Sri Lanka situation] is an excellent economic science experiment, horrible consequences.

Hate to point this out, but ammonia use as an energy vector unfortunately brings "food vs fuel" up again (see the bioenergy debate) since ammonia=food and livelihoods, but ammonia capacity is ramping up world wide, so hopefully not an issue in a few years.

Manure discussion:

Louise: Manure is a fine alternative for large agriculture. Where you have large commercial dairies and feedlots spreading manure from those entities usually is a very competitive and well balanced fertility program. However it has now also priced itself out of the market. Saying manure is only for gardens in the backyard is just not true for western Kansas agriculture for any size farm operation.

Mary: In what ways has spreading manure priced itself out of the market? Is this true even when anhydrous ammonia is $1500/tonne??

Vance: As soon as commercial fertilizer started going up, the area feedlots started charging for the manure. Historically they gave it away just to get rid of it. Now, however, they charge $5/ton because of the very high fertilizer prices. Thus, if you want to put on a standard 10 tons/acre, it will cost another $50/acre—jumping a $74/acre cost to $124. And with costs that high, manure becomes a very marginal fertilizer. You also have to realize that much of the nutrient value of manure is not immediately available—and won't be for several more years which creates even more economic problems because of the time value of money—buying a very expensive commodity that you won't get full use out of for several years into the future. Too, all this assumes you can even get the manure. Of the two major feedlots in Lane County, neither are allowing any manure to be picked up by farmers—either they are keeping it for their own use or for select customers. Use of manure is a very big business here in southwest Kansas where we have many large feedlots and dairies. And it is an excellent fertilizer especially if you are located close to a feedlot. But if you have to haul it very far, transportation costs just kill you. Now we have to deal with super high prices and lack of availability. In other words, there is no silver bullet.

Mary: Oh dear. They get you coming and going. How frustrating.

The technology is not ready yet, but local production of ammonia like we are evaluating is looking better all the time – for the midwest US, for Sri Lanka, and many places. Between local production of renewable energy and ammonia, and precision irrigation so the nitrate is not such a pollution hazard, the future has some good options. But we are not there yet and things are hard now. And people need to eat. It is good to be working on a solution. A hard time with a viable goal in mind brings hope.

New plan for user software produced by FEWtures

As part of FEWtures we are working with stakeholders to produce apps to convey our findings about the science, economics and impact on local communities of renewable energy powered ammonia production and water treatment. The goal is for stakeholders to be able to understand how these innovations might fit into their future plans.

From the perspective of how to represent the agricultural aspects of the analysis, two options have been discussed that result from different ideas of how much users of such an app will want to control the agricultural part, as indicated in this figure.

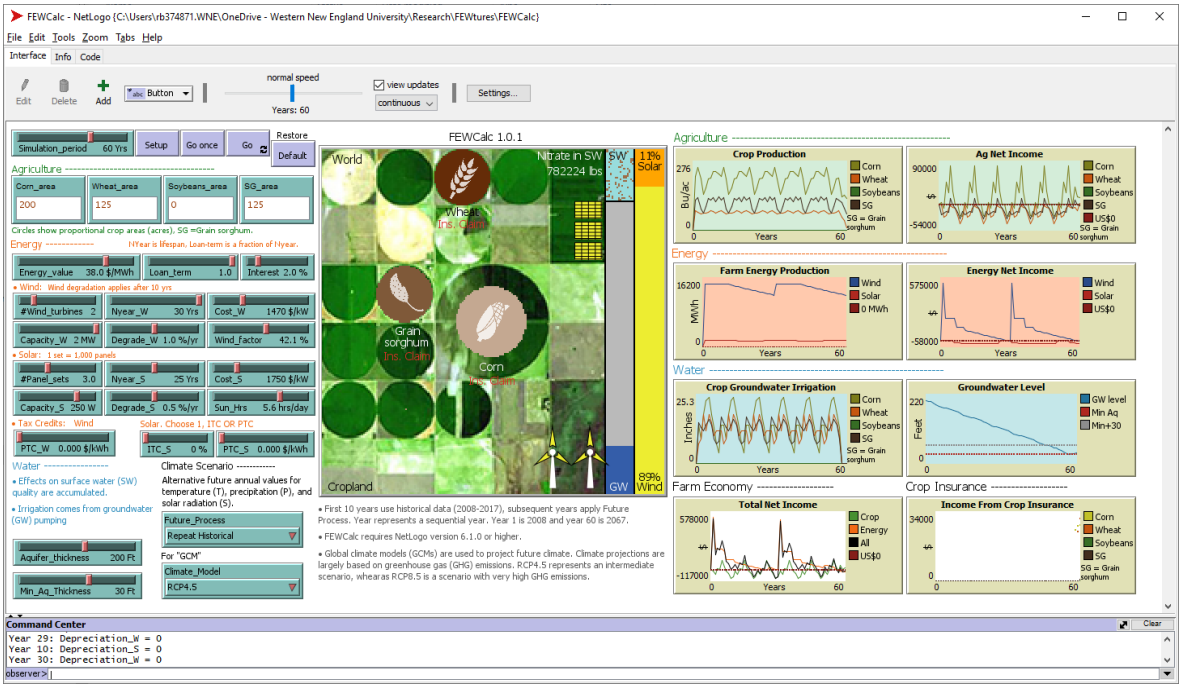
One option is to have an app that uses information about climate, crop varieties, and so on to develop a model (a virtual reality) of the agricultural system (App A in the figure). The model calculates water and fertilizer demand and agricultural production given different locations, water availability, and climate conditions. The agricultural model we would use is widely accepted and is called DSSAT. TheDSSAT results are combined with economic data to investigate financial consequences. We call App A FEWCalc.

The other option is to have an app that solicits information from the user to determine water and fertilizer demand and agricultural production given different locations and climate conditions. This app would ask questions of the user to provide this information. We call App B the SDM (systems dynamic model)

In other ways the two apps would be built using the same information. This information is being developed in FEWtures by the teams, as described below.

Both apps would be readily available and people could go back and forth between them.

Here is an image of what the FEWCalc interface for FEWtures App A currently looks like.

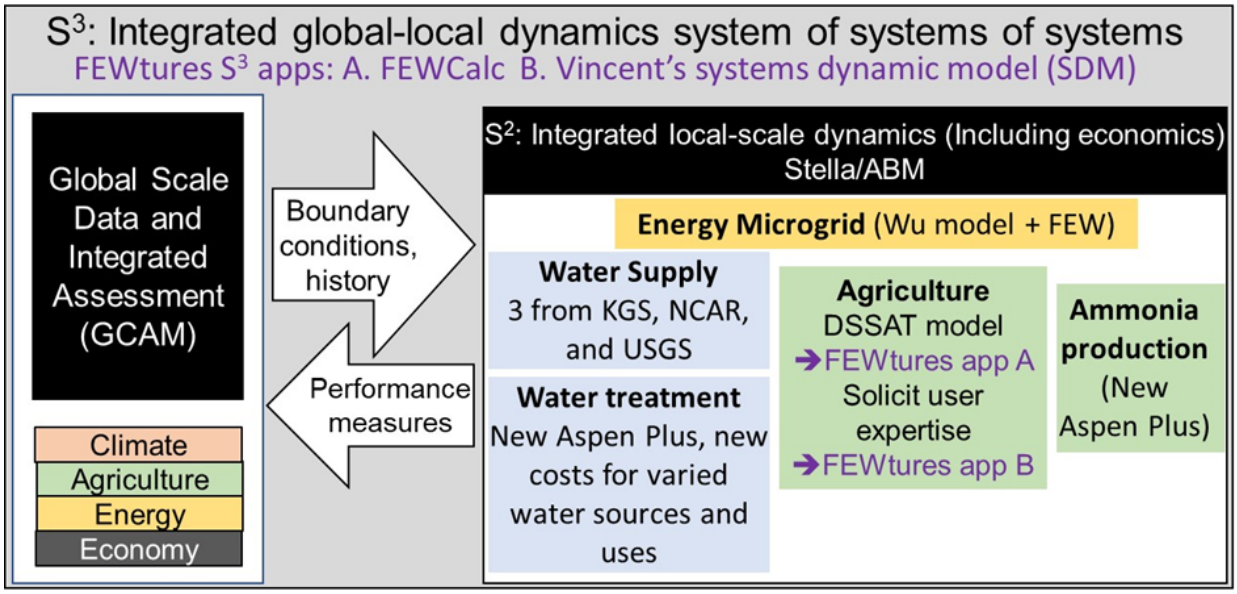


Team Updates

This is what the FEWture Teams are doing to build the science, technology, and community to make the two apps accurate and influential.

- **Global Interactions** (Robert Barron, PhD Student Nanaadom Nyarko)
    - The global interactions team models socioeconomic, technological, and environmental systems at the global scale. We use the Global Change Analysis Model (GCAM), a global-scale Integrated Assessment Model (IAM) to provide the global climate and economic drivers that influence local opportunities.
        - PhD student Nanaadom Abayie Nyarko (Adom) is developing expertise in GCAM. The model is running and reasonable results are being obtained. We are currently deploying GCAM to the University of Kansas High-Performance Computing Cluster, which will greatly increase the speed and capacity of our modeling capabilities.
        - Global interactions meeting with the other FEWtures teams to define their data needs, and develop a list of their data needs. The following is a partial list of the data that will be exchanged:
            - Global prices for crops, energy, and nitrogen fertilizer.
            - Global demands for crops, energy, and fertilizer.
            - Long-term climate projections.

        - We have begun working to improve FEWCalc (FEWtures App I). We are currently working to deploy FEWCalc to the web and improve its user interface. Longer-term goals include improving FEWCalc's capabilities, including adding variable energy prices and configuring it to work with GCAM data.
    - FEWCalc User Interface. The Global team is working with undergrads at WNEU to deploy FEWCalc to the web and improve the user interface.
- **Economic-technological modeling** (Vincent Amanor-Boadu, PhD student Catherine Obiribea Ofori-Bah)
    - Economic analysis of local green ammonia. Preliminary analysis looks promising for some alternatives of financing the capital costs.
    - The techno-economic model supporting firm level decision making developed by this team will be included in both FEWtures Apps.
    - Paper on "Directing the Wind: Techno-Economic Feasibility of Green Ammonia for Farmers and Community Economic Viability" submitted for publication in Renewable Energy. The editor found the paper "too specific from an economic and financial perspective" and rejected it. The paper is being reframed for another journal that could find it appropriate.
    - Wind-to-Ammonia Economics



for Farmers and Community Leaders workshop, led by Dr. Vincent Amanor-Boadu

- An outreach took place on March 4, 2022 in Syracus KS to 15 crop and livestock farmers and community leaders from four counties surrounding Hamilton County, KS.
    - Participants explored the economics of a dozen wind energy-to-ammonia solutions for alternative production levels and alternative anhydrous ammonia prices.

            - The analyses focused on modular farm-level solutions and evaluated the potential community venture support from the savings on fertilizer costs as a tax minimization and community viability enhancing strategy.
        - Dr. Amanor-Boadu is available to conduct similar workshops in communities upon request.
- **Ammonia production** (Peter Pfromm, PhD student Wrya Aframehr)
    - Find way to produce ammonia at lower pressure, which would have economic and operational advantages
        - Paper published, Mohammadi Aframehr, W., Pfromm, P. H., "Activating Dinitrogen for Chemical Looping Ammonia Synthesis: Nitridation of Manganese", Journal of Materials Science, (Impact Factor 3.55, 2019), 56(22), 12584-12595, 2021
        - Paper published: Mohammadi Aframehr, W., Pfromm, P. H., 2021, "Activating Dinitrogen for Chemical Looping Ammonia Synthesis: Mn nitride layer growth modeling", Chemical Engineering Science, (Impact Factor 4.3, 2021), 117287
        - Wray Mohammadi Aframehr successfully completed his PhD March 4, 2022
    - Solid oxide electrolysis (SOEC) continues to be revisited as a significant improvement (energy demand reduced by 30%) regarding the energy demand of electrolysis of water to produce hydrogen compared to conventional electrolysis. The Fall 2021 FEWtures newsletter provided some details and Wrya's publications are related to this advance as well. We continue monitoring this technology and consequences for the proposed local ammonia production investigated in FEWtures.
- **Water treatment** (Ted Peltier, Peter Pfromm, postdoc Alban Echchelh)
    - Working on the programming needed to bring water treatment into the FEWtures apps and to publish the innovative aspects of this work. Alban is completing this work from his new position in England.
- **Electric microgrid** (Hongyu Wu, PhD students Lawryn Edmonds and Xuebo Liu)
    - We made progress in how a green ammonia plant might work in the context of typical characteristics of wind energy generation. This will be used in the FEWtures Apps described above.
        - Electricity-powered ammonia plants and the microgrid
            - 2022 IEEE Power and Energy Society General Meeting, to be presented in July 2022. Accepted paper titled "A Demand-Responsive Green Ammonia Plant and its Impact on the Electricity Distribution System" This work considers the coordinated operation of an electricity distribution system and an electricity-run green ammonia plant. The ammonia plant serves as a demand responsive load to the electricity distribution system (means it can turn off and on based on electricity availability). It also helps manage energy supplies through chemical energy storage in the ammonia.
            - Paper submitted to submitted to *Sustainable Energy, Grids and Networks.* A more in-depth journal paper with a similar topic titled

"Green Ammonia Production-Enabled Demand Flexibility in Agricultural Microgrids with Distributed Renewables". The flexible ramping capabilities of the ammonia plant and impacts on the distribution location marginal price are represented and evaluated. Further, the impact of a direct ammonia fuel cell for turning ammonia back into electricity is found to be useful during an emergency test case.

- Energy needs for ammonia production
  - An accurate ammonia mathematical model was completed and was used in the models mentioned above. With the help of Dr. Pfromm and the Ammonia Production Team, a small-scale green ammonia plant, and its electricity consumption, was modeled so that operation could be optimized when coupled to an electricity microgrid model. The ammonia plant was used as a demand-responsive load to follow the available renewable generation in the microgrid. Used in the models above?
- Considering long-term planning and uncertainty
  - We are designing scenario generation. Scenarios allow future uncertainty of the daily/weekly operation model to be used in the long-term, stochastic optimization FEWtures planning model. Scenarios are created based on electrical demand increases, wind and solar generation, battery capacity, grid-connected and microgrid conditions, and ammonia plant inclusion. The hope is that these scenarios could help decision-makers to make better choices under uncertain future conditions. Some of you are such decision makers. Let's talk about doing this well.

- Service and Outreach
  - **IEEE Kansas Power and Energy Conference 2022**. Dr. Hongyu Wu serves as a conference co-chair and PhD students Xuebo Liu and Lawryn Edmonds serve as technical committee members. This conference considers energy management and system operation research, among other topics.
  - **Kansas Governor's Water Conference Nov 2021**. PhD student, Lawryn Edmonds presented her work on the coupling between daily operational models of electricity distribution and drinking water networks as a poster. The link for the video presentation of the poster is found here. The link to the poster pdf is found here; depending on your computer settings, clicking the link may open the pdf file or place it in your download directory.

- **Stakeholder Engagement and Policy** (Mary Hill, Susan Stover, Ben Gray)
  - Stakeholder surveys and interviews
    - Online survey to gauge producers' farming situations is complete. 215 unique surveys collected. Ben Gray and Jim Bloodgood are working on the analysis and manuscript.

        - Semi-structured surveys are being planned by Vincent Amano-Boadu to obtain additional information which in part will be used to guide development of the FEWtures apps discussed above.
    - Renewable energy legislation status in the 5 states of the Central Arkansas River Basin (CARB)
        - Kansas: Anti-wind legislation is being introduced in the legislature as SB253; look Here and here.
        - Colorado: Requirement for utilities using 100% renewables by 2035 is being discussed; see here.
        - Texas: In 2021, in a bill aiming to address electric grid vulnerabilities revealed in the 2/2021 cold snap, efforts to restrict renewable energy development were unsuccessful and SB1 and 2 were enacted; see here.
        - New Mexico: 2019 committed the state to 50% renewable electricity by 2030 and 80% by 2040. In 2022, the governor announced the introduction of House Bill 4, the **Hydrogen Hub** Development Act to develop low-carbon hydrogen; see here. No specific energy vector, such as ammonia, was mentioned,
        - Oklahoma: Have a voluntary goal of 15% of electricity being renewable by 2015; see here. There does not seem to be legislation actively being pursued in 2022.
    - Links to presentations about the project, either as a video or images. More focused disciplinary presentations are listed under other team contributions.
        - Geological Society of America, Portland, OR 10/12/202`
            - *Capturing Wind for Food-Energy-Water in the High Plains*, S. Stover and M.C. Hill, Link to abstract and talk slides and narration.
        - American Geophysical Meeting 12/2021 New Orleans
            - *FEWtures: Building Rural Economies, Reducing Carbon and Supplying Food for the Future*, M.C. Hill, S. Stover, V. Amanor-Boadu, P. Pfromm, L. Edmonds, R. Barron, H. Wu, and M. Phetheet. Poster.
- **Business Innovations** (Jim Bloodgood)
    - Will producers use the innovations we develop? We are surveying, interviewing, and building technology acceptance models to best determine who is most likely to adopt these innovations.
        - Our goal is to identify a process for enhancing adoption where it can most increase benefits to producers.
    - Initial survey results were presented in the fall 2021 newsletter. Jim Bloodgood and Ben Gray are working on the analysis and article.
    - Structured interviews are being developed with Vincent Amanor-Boadu.
- **Water Supply** (Andrea Brookfield, Sam Zipper, PhD student Patience Bosompemaa)
    - How are we quantifying the impact of pumping on groundwater levels?
        - Linear data-based relationships developed by KGS are being used to quantify the impacts of different pumping reduction scenarios. We are investigating how these might be used in other states within the CARB region that do not have as detailed of groundwater use and groundwater level data.

- How are we quantifying the impact of water use on streamflow?
  - USGS National Hydrologic Model (NHM). Our first step is to compare NHM and simulated streamflows to USGS streamflow observations for the CARB. Results show greater discrepancy than expected. We are checking to see how the model represents water use as a potential explanation. This could dramatically affect how the NHM could be used for our work.
- Use historical streamflow to understand how and why surface water availability has changed in the Arkansas River.
  - Arkansas River near Larned
    - Continue ongoing monitoring of surface water-groundwater interactions in an intermittent section of river (that is, the section of river sometimes has streamflow and sometimes does not have any streamflow) to augment the existing 23 years of data.
    - Evaluate the relative importance of climate, pumping, and diversions on streamflow using a mixture of historical data and time series models.
  - Evaluate temporal trends in baseflow and other hydrologic metrics in streams of the CARB region.
  - Manuscript currently in review at *Environmental Research Letters:* "Alternative stable states and hydrological regime shifts in a large intermittent river", Zipper et al.
  - Presentation at the American Geophysical Union Meeting, New Orleans, Dec 16, 2021. *Flow regimes and alternate stable states in a non-perennial river*, Zipper Samuel C Zipper, Kyle Compare, Ilinca Popescu, Erin Cedar Seybold and Chi Zhang, Link to poster pdf.

- **Resilience Metrics** (John Symons, Amir Modaressi)
  - Development of **resilience metrics** for use by a wide audience is by its very nature imprecise.
    - Resilience means different things to different people, and the FEW systems of concern have many parts with complex interdependencies. Our FEWtures project is one of the first efforts in this arena.
    - We will bravely work with you to create measures that produce useful insights about resilience in the FEWtures Apps.
  - Presentation at the American Geophysical Union Meeting, New Orleans, Dec 16, 2021. *Modeling resilience for Food, Energy, and Water Systems*, Amir Modarresi Afamehr, John Symons, Mary Hill. Link to poster pdf.

Thank-you for joining us! We look forward to seeing you on Zoom On October 20, 2022!

With best regards,

Mary and the FEWtures Teams

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