



www.acs.org/acswebinars

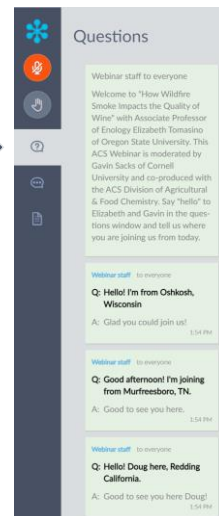


Questions or Comments?

Type them into the questions box!



"Why am I muted?"
Don't worry. Everyone is muted except the Presenter and the Host. Thank you and enjoy the show.



1

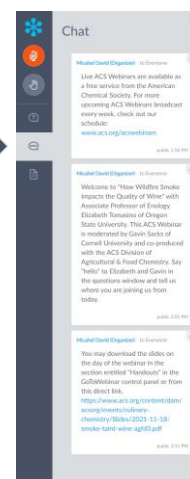
1



www.acs.org/acswebinars



Chat
Announcements and hyperlinks from our team



2

2

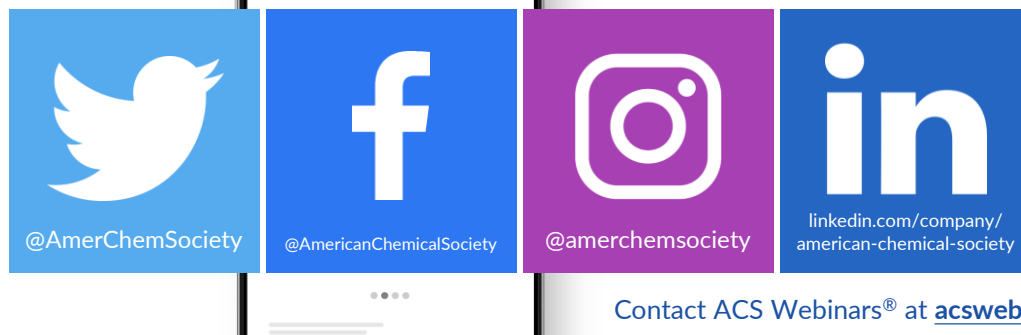


www.acs.org/acswebinars



Let's Get Social!

Follow the American Chemical Society on Twitter, Facebook, Instagram, and LinkedIn for the latest news, events, and connect with your colleagues across the Society.



Contact ACS Webinars® at acswebinars@acs.org

3



www.acs.org/acswebinars



Where is the Webinar Recording?



All Registrants

Watch the unedited recording linked in the **Thank You Email** for 24 hours.



ACS Members w/Premium Package

Visit the [ACS Webinars® Library](#) to watch the **edited and captioned** recording.

4

4



Looking for a new science podcast
to listen to?



Check out Tiny Matters, from the American Chemical Society.



Sam Jones, PhD
Science Writer & Exec Producer



Deboki Chakravarti, PhD
Science Writer & Co-Host

TO SUBSCRIBE
visit <http://www.acs.org/tinymatters> or
scan this QR code



5

ACS Industry Member Programs

- **ACS Industry Matters**

ACS member only content with exclusive insights from industry leaders to help you succeed in your career. #ACSIndustryMatters

Preview Content: [acs.org/indnl](https://www.acs.org/indnl)

- **ACS Innovation Hub LinkedIn Group**

Connect, collaborate and stay informed about the trends leading chemical innovation.

Join: bit.ly/ACSinnovationhub

6

A Career Planning Tool For Chemical Scientists



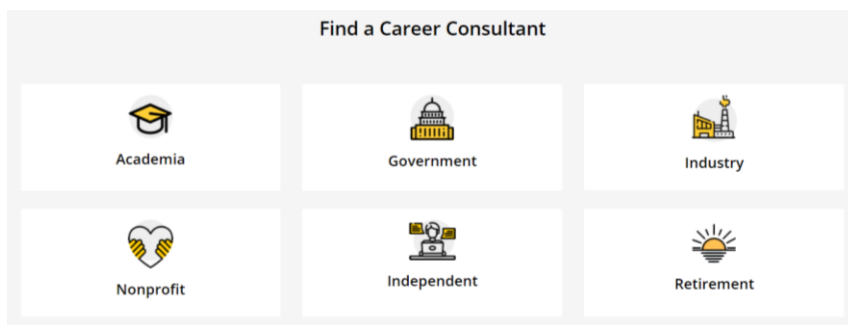
ChemIDP is an Individual Development Plan designed specifically for graduate students and postdoctoral scholars in the chemical sciences. Through immersive, self-paced activities, users explore potential careers, determine specific skills needed for success, and develop plans to achieve professional goals. **ChemIDP** tracks user progress and input, providing tips and strategies to complete goals and guide career exploration.

<https://chemidp.acs.org>

7

7

Career Consultant Directory




- ACS Member-exclusive program that allows you to arrange a one-on-one appointment with a certified ACS Career Consultant.
- Consultants provide personalized career advice to ACS Members.
- Browse our Career Consultant roster and request your one-on-one appointment today!

www.acs.org/careerconsulting

8

8



ABC Chem
ATLANTIC BASIN CONFERENCE ON CHEMISTRY

CHEMISTRY BIOLOGY & HEALTH
GREEN CHEMISTRY
MATERIALS & NANO
EDUCATION & SCIENCE COMMUNICATIONS

Atlantic Basin Conference on Chemistry

Linking the World through Chemistry

13-16 DECEMBER 2022 | MARRAKECH, MOROCCO

HOTEL: MÖVENPICK HOTEL MANSOUR EDDAHBI MARRAKECH
CONVENTION CENTER: PALAIS DES CONGRÈS MARRAKECH

ABCChem.org #ABCChem2022

REGISTER TODAY
ABCChem.org

9

ACS Career Resources



Professional Development & Education



ACS Professional Education
Career and training opportunities from leading experts to help you stay current and advance your career.



ACS Leadership Development
A suite of flexible, free and online courses for growing your leadership skills in today's global economy.



ACS Institute
An online learning center that offers a virtual collection of learning and training resources taught by leading experts.



Virtual Classrooms
Brought to you by ACS Career Pathways™, free online courses offer useful expertise to help you reach your career goals.



ACS Webinars
Hundreds of webinars presented by subject matter experts in the chemical enterprise.



Career Events
Free webinars and networking opportunities for mid-career chemistry professionals.



ACS Job Campaign
Free events where students can meet with job recruiters, hear your story from ACS editors, and get career tips.



Podcasts for Faculty Workshop
An online workshop for job seekers to find career in newly positions in the chemical enterprise.



Career Kick-Starters Workshop
A one-day career development workshop for graduate students and postdoctoral fellows.

Managing Your Career



ACS Career Pathways™
Helping building and career chemists design careers in industry, higher education, government and starting for yourself.



Career Consultants
Personalized consulting services to help you make strategic career decisions and find success in your job search.



ChemIDP™
ACS Career Development Platform for graduate students and postdoctoral fellows.



Résumé Review
Experts help you to update a résumé with a professional to support your job search habits.

Register for a 2022 Virtual Office Hour

4 AUG	Is Grad School Right for Me? August 4, 2022	1 SEP	Leadership and Soft Skills Development - What You Need to Advance in Your Career September 1, 2022
6 OCT	Skydiving into Retirement October 6, 2022	3 NOV	Finding and Securing an Internship November 3, 2022
1 DEC	Careers in Academia December 1, 2022		

<https://www.acs.org/content/acs/en/careers/personal-career-consulting.html>

<https://www.acs.org/content/acs/en/careers/developing-growing-in-your-career.html>

10

10

ACS Bridge Program

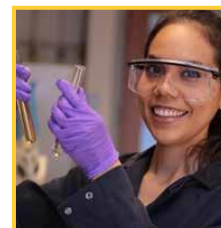


Are you thinking of Grad School?

If you are a student from a group underrepresented in the chemical sciences, we want to empower you to get your graduate degree!

The ACS Bridge Program offers:

- A FREE common application that will highlight your achievements to participating Bridge Departments
- Resources to help write competitive grad school applications and connect you with mentors, students, and industry partners!



Learn more and apply at www.acs.org/bridge

Email us at bridge@acs.org

11

11

Get in touch with the Office of Diversity, Equity, Inclusion & Respect

The Office of Diversity, Equity, Inclusion & Respect (DEIR) is the central hub at the American Chemical Society that coordinates, supports, and guides all efforts by staff, members, and governance toward Strategic Goal 5, "Embrace and Advance Inclusion in Chemistry." The Office of DEIR at ACS is committed to empowering everyone, irrespective of lived experience and intersectionality of identities, to fully participate in the chemistry enterprise. The Office of DEIR welcomes comments, suggestions, and questions around issues of diversity, equity, inclusion, and respect from members at any time. Please do not hesitate to reach out to the Office through this form.

Please do not hesitate to reach out to the Office of DEIR at diversity@acs.org

<https://fs7.formsite.com/acsdiversity/ACSMemberFeedback/index.html>

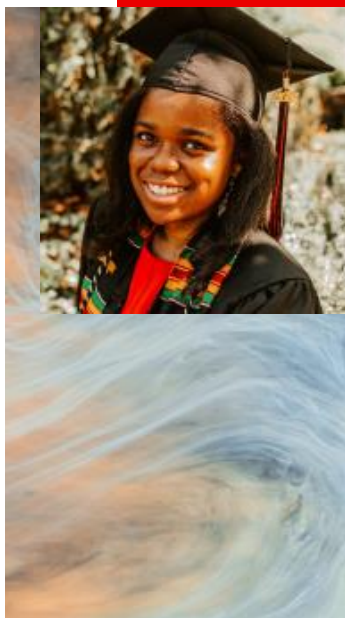


12

12

ACS Scholar Adunoluwa Obisesan

BS, Massachusetts Institute of Technology, June 2021
(Chemical-biological Engineering, Computer Science & Molecular Biology)



“The ACS Scholars Program provided me with monetary support as well as a valuable network of peers and mentors who have transformed my life and will help me in my future endeavors. The program enabled me to achieve more than I could have ever dreamed. Thank you so much!”

GIVE TO THE
ACS SCHOLARS PROGRAM

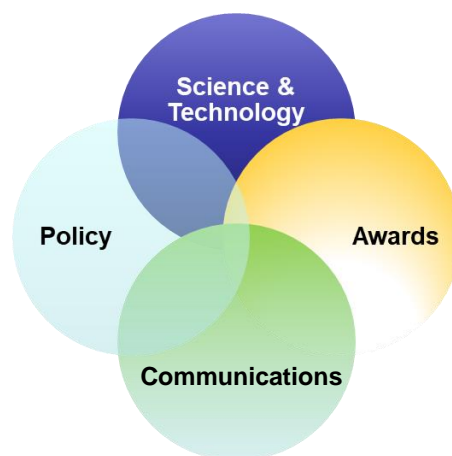
Donate today at www.donate.acs.org/scholars

13

ACS Committee on Science (COMSCI)



“The ACS Committee on Science aims to **engage the global chemistry enterprise to build a better tomorrow** by identifying new frontiers of chemistry, examining the scientific basis of, and formulate public policies related to, the chemical sciences, and recognizing outstanding chemical scientists.”



<https://www.acs.org/content/acs/en/about/governance/committees/science.html>

14

14

Chemistry & the SDGs



SUSTAINABLE DEVELOPMENT GOALS


<https://www.acs.org/content/acs/en/sustainability/chemistry-sustainable-development-goals.html>

15

15



www.acs.org/acswebinars



Wed., Aug. 17, 2022 | 2:00pm-3:00pm ET

Catalizadores de la Reducción de CO₂ con Gran Promesa

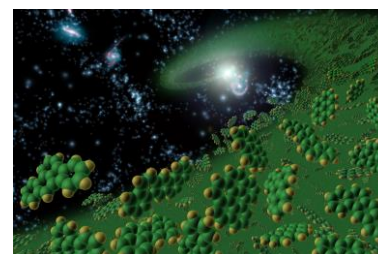
Co-produced with the Sociedad Química de México



Thurs., Aug. 18, 2022 | 2:00pm-3:00pm ET

An Evolutionary Mystery: Mirror Asymmetry in Life and in Space

Co-produced with the Astrochemistry Subdivision of the American Chemical Society



Wed., Aug. 31, 2022 | 2:00pm-3:15pm ET

How We Study Molecules in Space

Co-produced with the Astrochemistry Subdivision of the American Chemical Society

Register for Free

Browse the Upcoming Schedule at www.acs.org/acswebinars

16

16



www.acs.org/acswebinars



**THIS ACS WEBINAR®
WILL BEGIN SHORTLY...**

👋 Say hello in the
questions window!



17

17



www.acs.org/acswebinars



Download the Presentation
Slides Under the Handouts
In GoToWebinar Panel



ACS Webinars®
CLICK • WATCH • LEARN • DISCUSS

Frontier Fridays: Putting Sustainable Chemistry to Work in Manufacturing



RYAN LIVELY, PhD

Assistant Professor,
Georgia Institute of Technology



Mark Mascal, PhD

Professor of Chemistry,
University of California Davis



ADELINA VOUTCHKOVA-KOSTAL, PhD

Director of Sustainable
Development, ACS

This ACS Webinar® is co-produced with ACS Committee on Science and the ACS Office of Sustainable Development

18

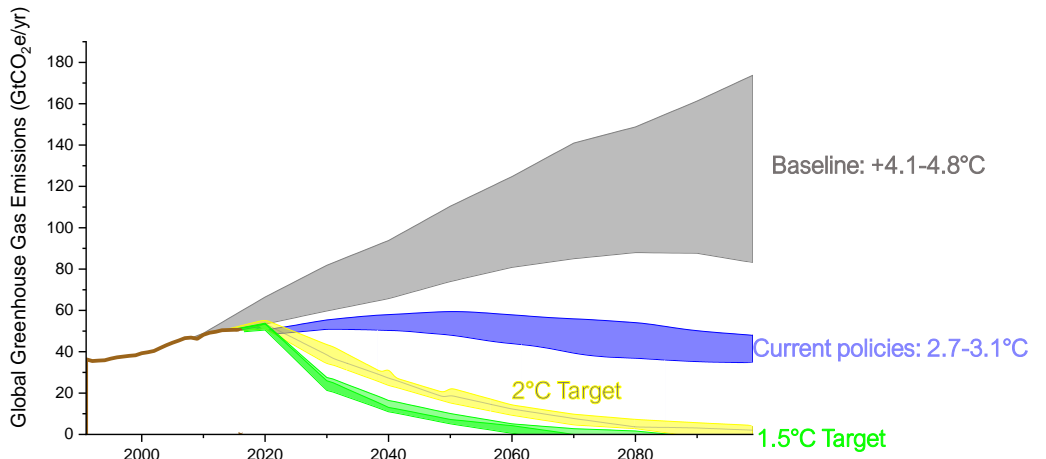
18

The Refinery of Today, Tomorrow, and the Future

Ryan P. Lively
August 2022
ACS Webinar



Climate change and carbon emission scenarios





Audience Survey Question

ANSWER THE QUESTION ON THE INTERACTIVE SCREEN IN ONE MOMENT

Will we the use of hydrocarbons be by 2050?

- We will use less hydrocarbons than we do today
- We will use about the same amount
- We will use more than we do today

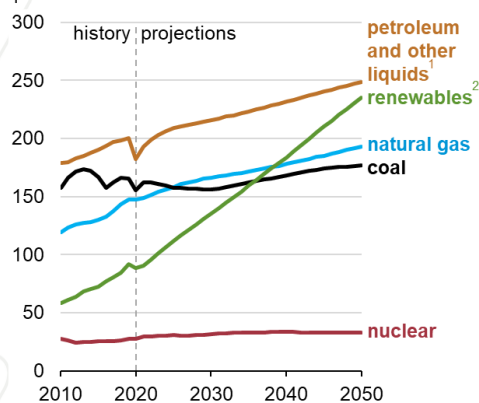
* If your answer differs greatly from the choices above **tell us in the chat!**

21

21

Speculation: population growth in developing regions will more than offset growth in renewables

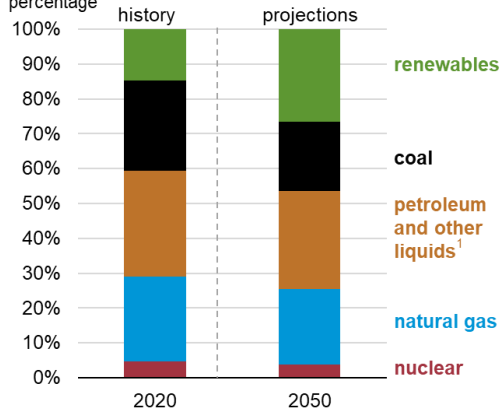
Primary energy consumption by energy source, world
quadrillion British thermal units



¹ Includes biofuels

² Electricity generation from renewable sources is converted to Btu at a rate of 8,124 Btu/kWh

Share of primary energy consumption by source, world
percentage



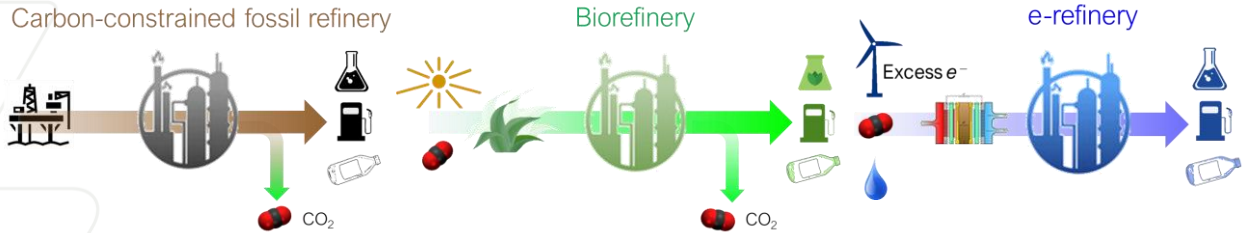
The future may require *more* hydrocarbons, not less!
...but with significantly reduced carbon emissions...

22

The Refinery of Today, Tomorrow, and the Future:

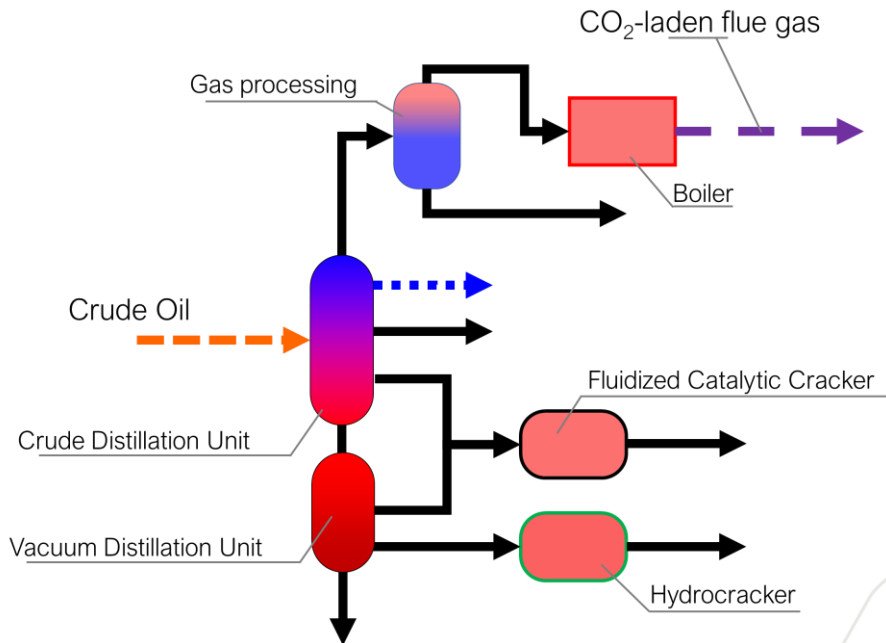
Producing *more* fuels, chemicals, and plastics with dramatically *lower* CO₂ emissions

The three low-carbon archetypes:



Speculation: existing capital equipment, permitting, zoning, and regulations provides strong driving force to evolve existing systems and switch the fuel source

Speculation: refinery flowsheet will reconfigure during energy transition



Speculation: advanced separations will play a critical role in future refineries

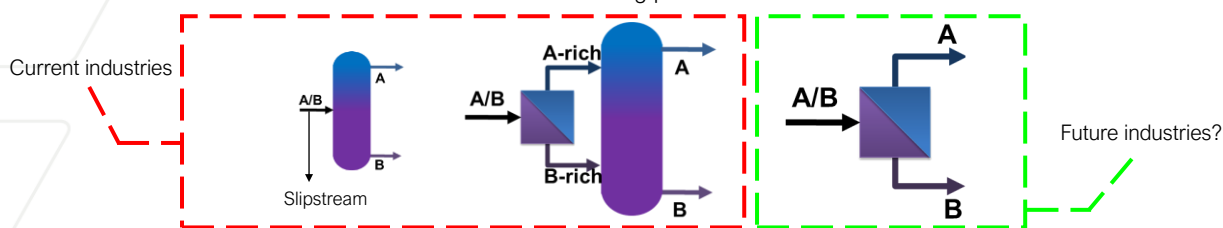
+ CO₂ removal from air

RP Lively, AIChE J 2021

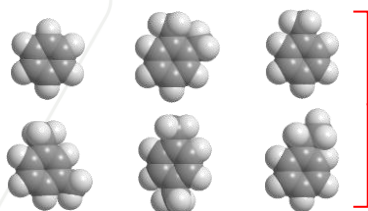
25

Membranes play a key role in the energy transition

Modular membrane systems can reduce carbon/energy intensity of existing manufacturing paradigms and enable futuristic manufacturing platforms!



Most current and future chemicals, fuels, and commodities involve the separation of "small" molecules < 300 Da

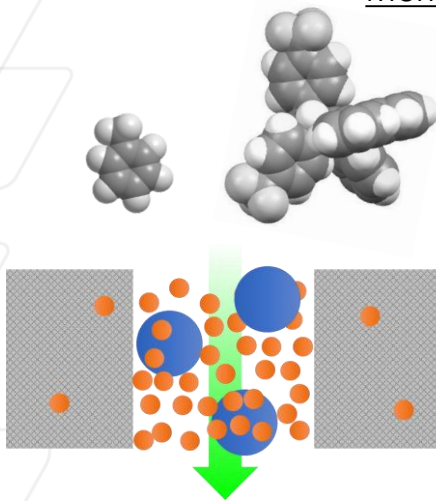


Real mixtures are often concentrated liquids and are complex



26

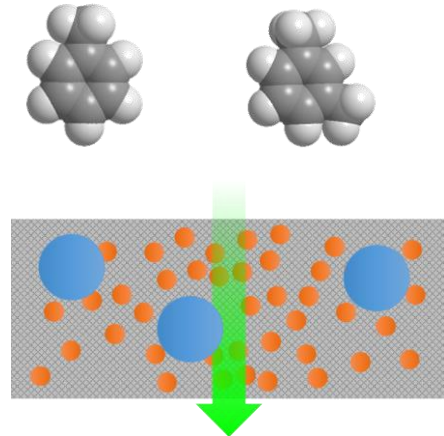
Membrane fundamentals



$$N_i \propto \Delta p, \ell^{-1}$$

Filtration; separation based on sterics + interaction with membrane surface

P. Marchetti, *Chem. Rev.* 2014, 114(21), 10735-10806



$$N_i \propto \Delta C_i^m, \ell^{-1}$$

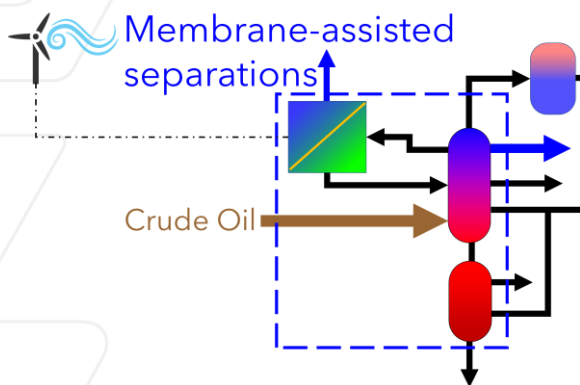
Permeation; $\mathbb{P}_i = D_i \cdot S_i$, separation based on sorption into membrane bulk and guest diffusivity

27

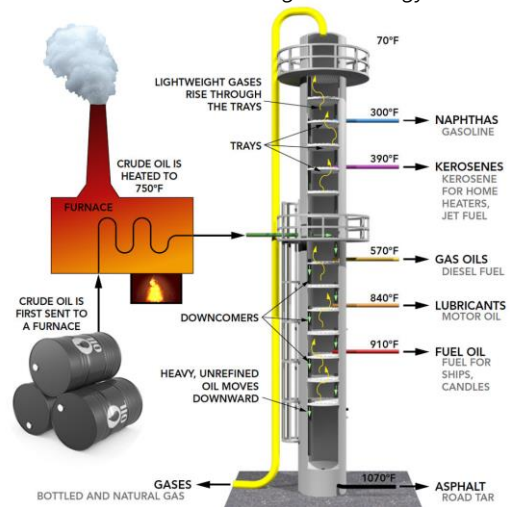
27

Examples of emerging separations technologies: crude oil fractionation

Crude oil fractionation: ~0.5-1% global energy consumption

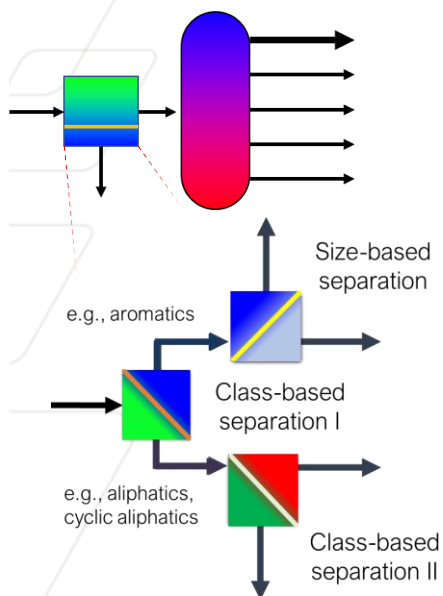


Energy and carbon intensity reductions by 1.5-2x!



28

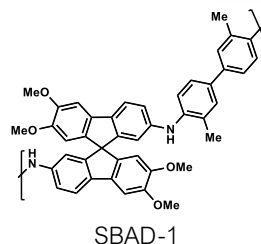
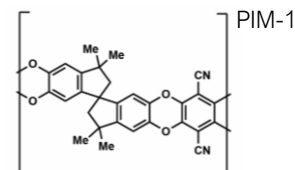
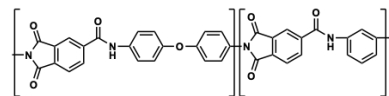
Membrane-based fractionation of complex mixtures



Membrane design challenges

- Stability in the presence of aggressive feeds
- Balance between productivity and efficiency
- Scalability

Torlon

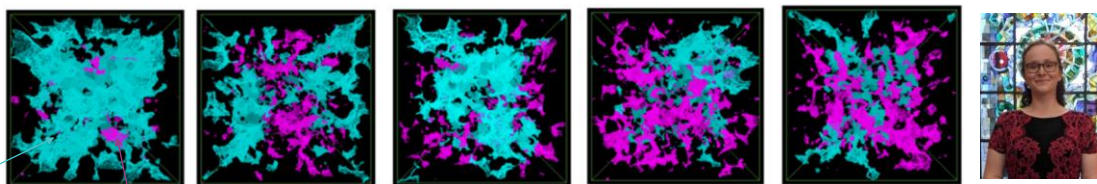


B.A. McCool et al. US20190367820A1, 2019

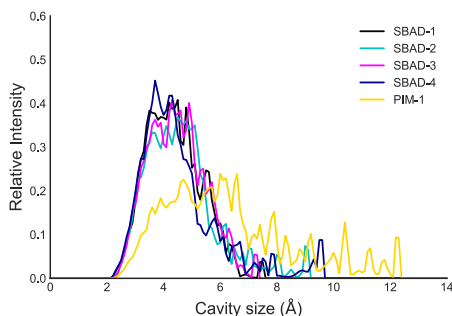
KA Thompson et al. Science, 2020, 369, 310-315

29

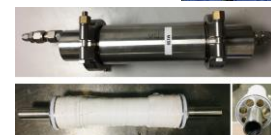
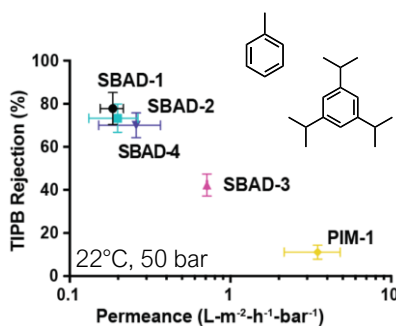
Relating polymer structure to membrane microstructure to guest transport

Interconnected
pore structurePIM-1
Isolated pore (accessible via chain motions)

Kim Jelfs

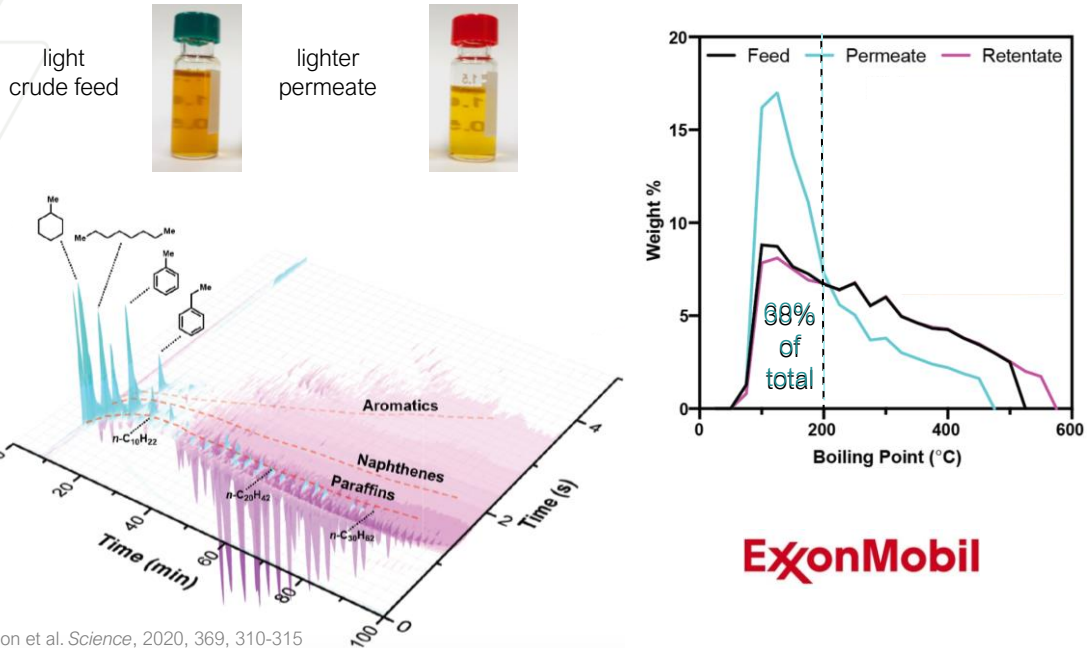
Andrew
Livingston

KA Thompson et al. Science, 2020, 369, 310-315



30

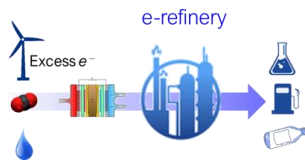
Complex mixture separations in action – real mixtures



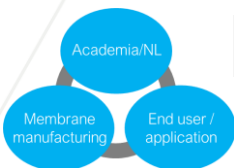
31

Review and Final Thoughts

- Existing refineries may “retool” to incorporate electrically-driven processes, bio-based feedstocks, and advanced separations
- Some “e-refinery” pilots are being constructed



- Membranes have the potential to enable more efficient refining processes (chemical, petro, bio, e-, ...)
- Identification of key win-win separations within the various refining processes (>100) remains a challenge
- How do we rapidly transition these new concepts out of the lab and into the field?



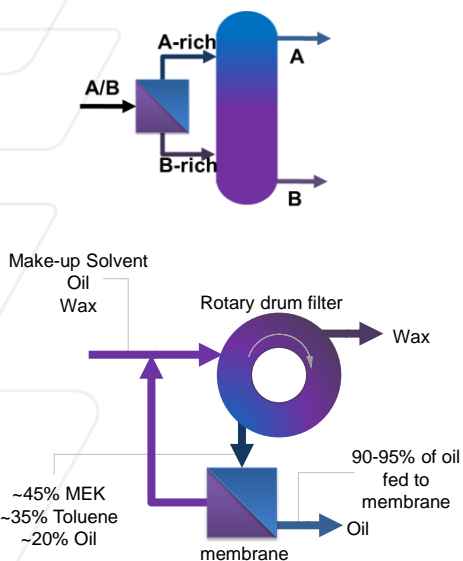
OSMOSES



Many opportunities and challenges await in separations science & engineering!

32

Key observations from successful membrane demonstrations



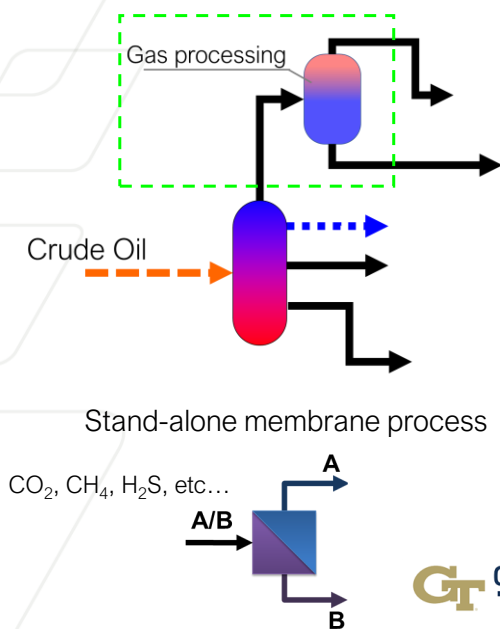
- 20% reduction in process energy intensity
- 20,000 tons/year reduction in GHG emissions
- Reduced VOC emissions by 125 tons/year
- Reduced water usage by 4 million gal/day
- Payback period <1 year; >600 days continuous operation



RM Gould et al., *Environmental Prog.* 2004, 20(1), 12-16

34

Pilot applications for membranes in chemical and petrochemical plants



Koros et al. *Ind. Eng. Chem. Res.* 2017, 56(37), 10482-10490

Lima Touma et al., *Offshore Tech. Conf.* 2019, OTC-29913-MS

35

The Story of 5-(Chloromethyl)furfural (CMF)



*Mark Mascall
UC Davis*

What is Chemistry's response to the climate crisis ?



Context: Green Chemistry, then and now

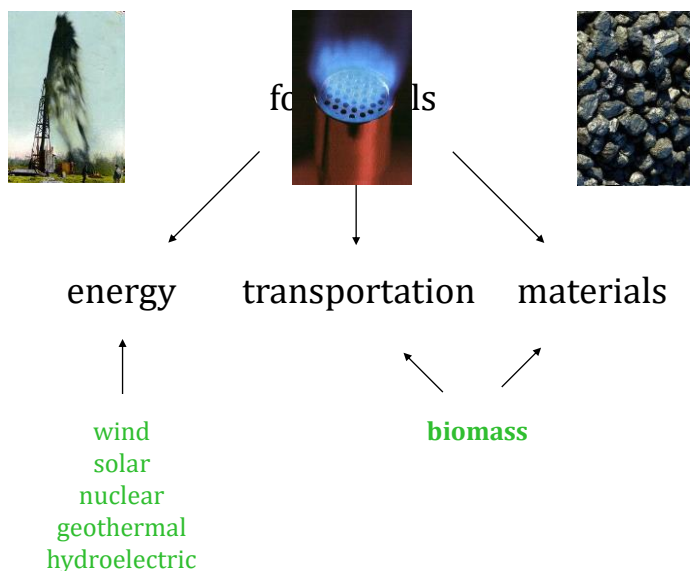
1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

Fewer hazards, less waste

vs

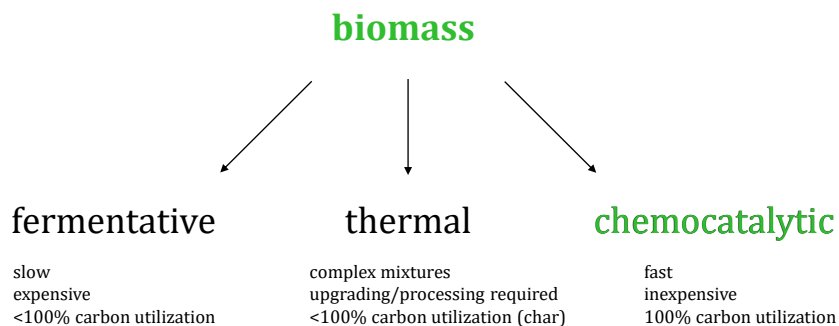


42



43

Biomass processing

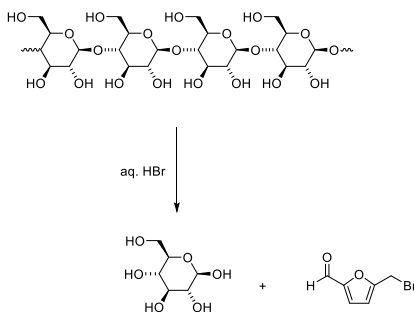


2006 UC Davis - Chevron

Joint Research Agreement

Biofuels Research: \$25 million/5 years

My Chevron Project



H. J. H. Fenton, M. Gostling, *J. Chem. Soc. Trans.* **1899**, 75, 423

XLI.—*Bromomethylfurfuraldehyde.*

By HENRY J. HORSTMAN FENTON, M.A., and Miss MILDRED GOSTLING,
B.Sc., Bathurst Student of Newnham College.

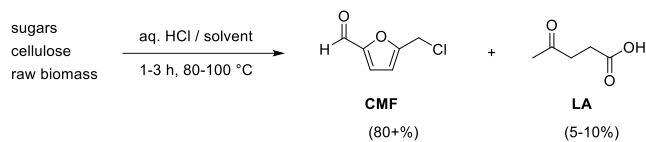
In a previous communication (*Trans.*, 1898, **73**, 554), it was shown by the present authors that certain carbohydrates, when treated with hydrogen bromide in ethereal solution, give an intense and beautiful purple colour. It was suggested that the reaction would probably be of service in distinguishing certain typical classes of carbohydrates, and that it might be employed for the detection of these in natural products.

The examination of a considerable number of carbohydrates of various classes led to the following generalisations.

1.—With *ketohexoses* (laevulose, sorbose), the purple colour appears after a few minutes, and becomes very intense in about one hour; and substances which, by hydrolysis, are capable of giving rise to these compounds (cane sugar, inulin) give a similar effect, only rather more slowly, the maximum colour being attained in about two hours.

2.—*Hexaldoses* (dextrose, galactose), and substances capable of giving rise to them (milk sugar, maltose, dextrin), show, in the first instance, various shades of yellow, brown, or red, and it is only after long standing that a purple colour is apparent. This colour, however, never approaches in brilliancy or intensity that obtained with substances mentioned in 1.

5-(Chloromethyl)furfural (CMF)



- CMF is a stable, low-melting solid (mp 37-38 °C)
- functional equivalent of and interconvertible with HMF
- product isolation a simple matter of evaporating solvent
- flow systems reduce reaction time to minutes

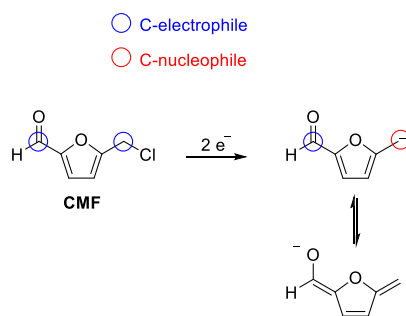
M. Mascal, E.B. Nikitin, *Angew. Chem. Int. Ed.* **2008**, *47*, 7924

M. Mascal, E.B. Nikitin, *ChemSusChem* **2009**, *2*, 859

M. Mascal, *US Patent* **2010**, 7,829,732

Review: M. Mascal, *ACS Sustainable Chem. Eng.* **2019**, *7*, 5588

CMF reactivity



H. Miao, N. Shevchenko, A. L. Otsuki, M. Mascal, *ChemSusChem* **2021**, *14*, 303

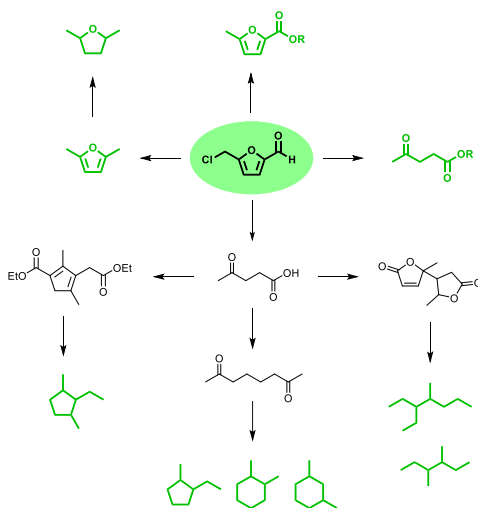
H. Miao, H. Ling, N. Shevchenko, M. Mascal, *Organometallics* **2021**, *40*, in press

CMF as a platform molecule



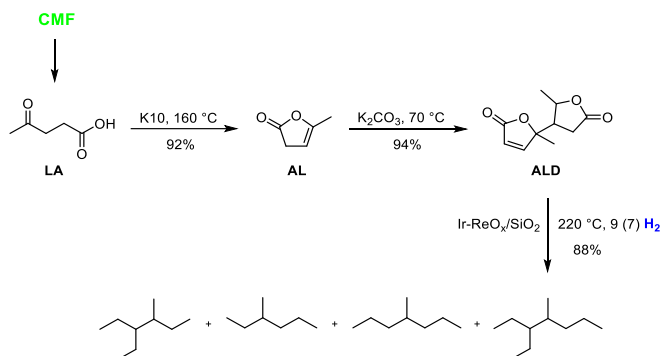
50

The CMF biofuel family tree



51

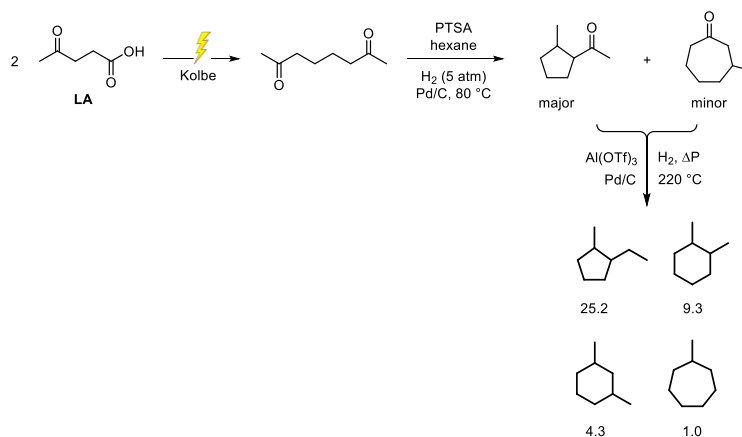
Fuels: Cellulosic gasoline 1



M. Mascari, S. Dutta, I. Gandarias, *Angew. Chem. Int. Ed.* **2014**, *53*, 1885

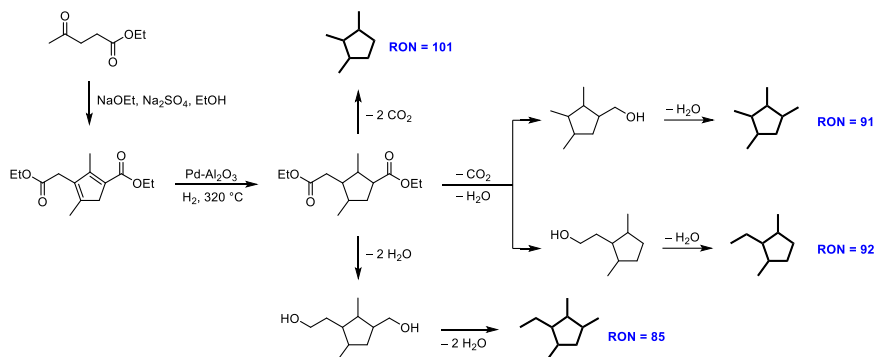
F. Chang, S. Dutta, M. Mascari, *ChemCatChem* **2017**, *9*, 2622

Fuels: Cellulosic gasoline 2



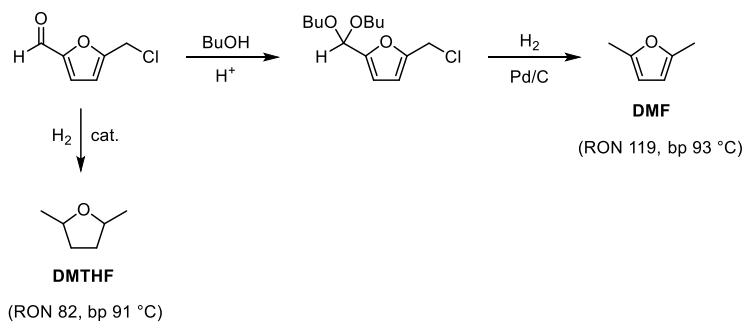
L. Wu, M. Mascari, T. J. Farmer, S. Perocheau Arnaud, M.-A. Wong Chang, *ChemSusChem* **2017**, *10*, 166

Fuels: Cellulosic gasoline 3



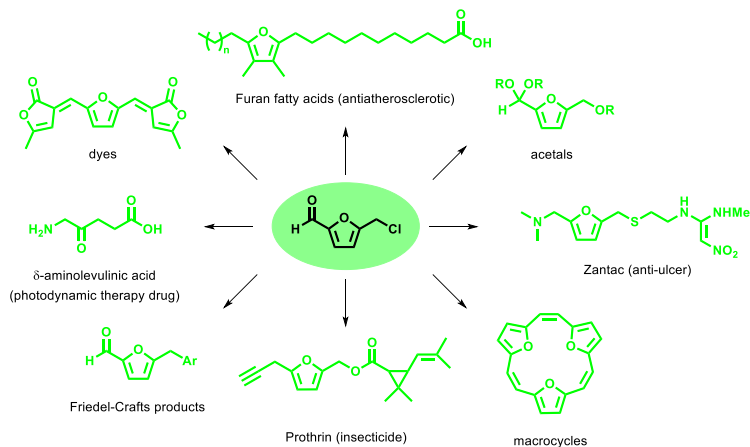
Z. Li, A. L. Otsuki, M. Mascal, *Green Chemistry*, **2018**, *20*, 3804

Fuels: Aromatics and oxygenates

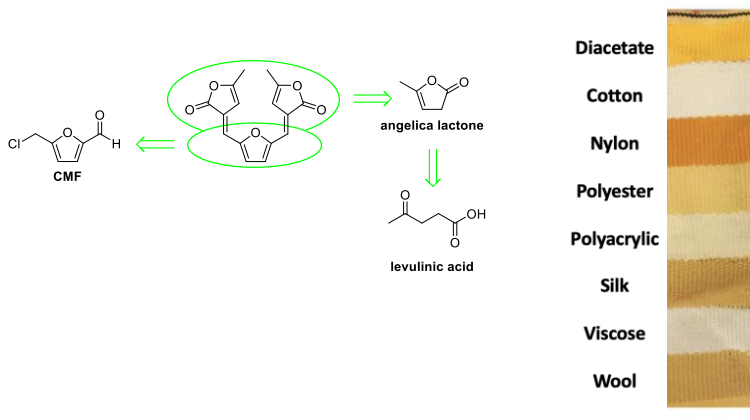


S. Dutta, M. Mascal, *ChemSusChem* **2014**, *7*, 3028

The CMF chemical family tree

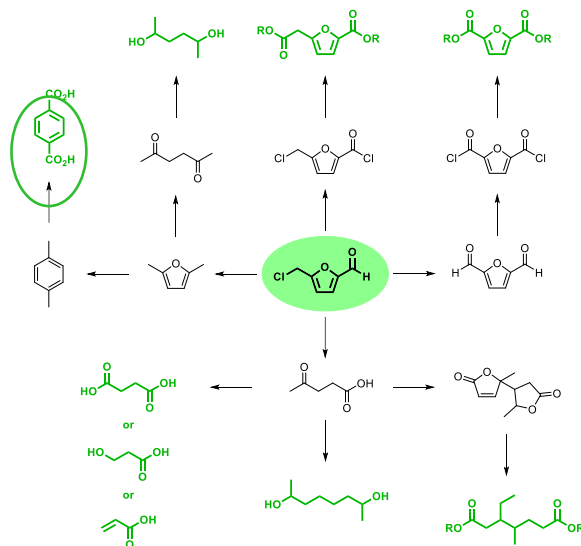


Biobased synthetic dyes from CMF



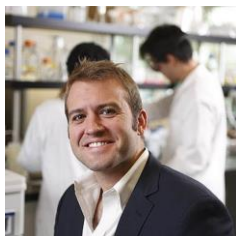
J. Saska, Z. Li, A. L. Otsuki, J. Wei, J. C. Fettinger, M. Mascal *Angew. Chem. Int. Ed.* **2019**, *58*, 17293

The CMF monomer family tree



58

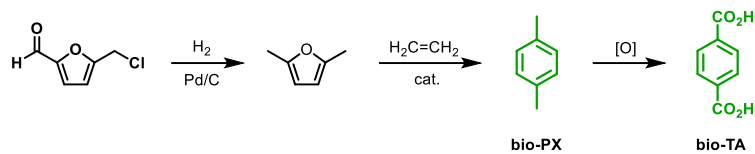
The Meeting



September 6, 2010

59

Monomers: terephthalic acid



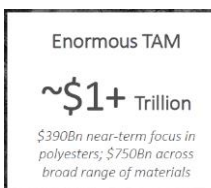
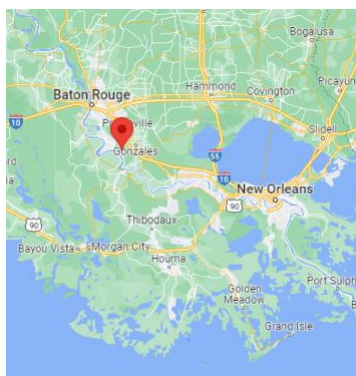
Monomers: terephthalic acid



Origin Materials (ORGN)
market cap >\$1B

Origin 1

Monomers: terephthalic acid

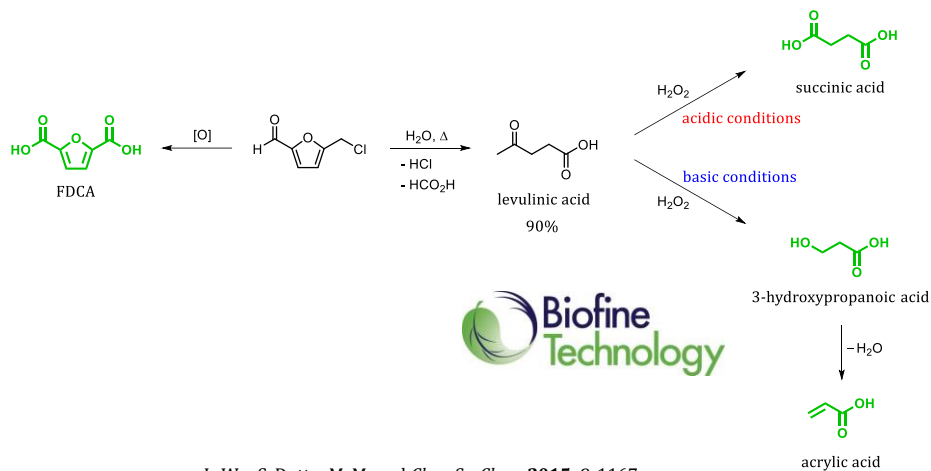


Origin 2 – Geismar, LA
Construction start 2023, commissioning mid-2025

EPA Green Chemistry Challenge Award



Monomers: succinic, 3-HPA, and bio-acrylic acid



L. Wu; S. Dutta; M. Mascal *ChemSusChem* **2015**, *8*, 1167

S. Dutta, L. Wu, M. Mascal, *Green Chem.* **2015**, *17*, 2335

S. Dutta, L. Wu, M. Mascal, *Green Chem.*, **2015**, *17*, 3737

Other CMF commercialization

Mercurius – Australia – cellulosic jet fuel

xF – Albuquerque, New Mexico – 408™ fuel additives

Furanica – Davis, California – furan fatty acids



Furanica

Acknowledgements – coworkers

Prof G K Nagaraja	Fei Chang
Dr Edward Nikitin	Jonatan Henschen
Dr Saikat Dutta	Maria Angelica Wong Chang
Dr David Lane	Zheng Li
Dr Linglin Wu	Edwin Naranjo-Valles
Dr Inaki Gandarias	Andrew Otsuki



Acknowledgements – Department of State



*The National
Academies of* | SCIENCES
ENGINEERING
MEDICINE

Thank You!



Postdoc positions available mjmascal@udavis.edu

Chemistry & the SDGs



SUSTAINABLE DEVELOPMENT GOALS



<https://www.acs.org/content/acs/en/sustainability/chemistry-sustainable-development-goals.html>



www.acs.org/acswebinars



**THE LIVE Q&A IS
ABOUT TO BEGIN!**

Keep submitting your questions
in the questions window!



70

70



www.acs.org/acswebinars



ACS Webinars
CLICK • WATCH • LEARN • DISCUSS



Wed., Aug. 17, 2022 | 2:00pm–3:00pm ET

**Catalizadores de la Reducción de
CO₂ con Gran Promesa**

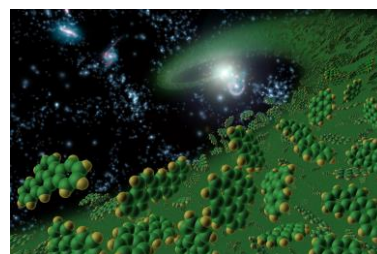
Co-produced with the Sociedad Química de México



Thurs., Aug. 18, 2022 | 2:00pm–3:00pm ET

**An Evolutionary Mystery: Mirror
Asymmetry in Life and in Space**

Co-produced with the Astrochemistry Subdivision of the
American Chemical Society



Wed., Aug. 31, 2022 | 2:00pm–3:15pm ET

How We Study Molecules in Space

Co-produced with the Astrochemistry Subdivision of the
American Chemical Society

Register for Free

Browse the Upcoming Schedule at www.acs.org/acswebinars

71

71



www.acs.org/acswebinars



Learn from the best and brightest minds in chemistry!

Hundreds of webinars on a wide range of topics relevant to chemistry professionals at all stages of their careers, presented by top experts in the chemical sciences and enterprise.



Edited Recordings

are an exclusive benefit for ACS Members with the Premium Package and can be accessed in the ACS Webinars® Library at www.acs.org/acswebinars



Live Broadcasts

of ACS Webinars® continue to be available free to the general public several times a week generally from 2-3pm ET. Visit www.acs.org/acswebinars to register* for upcoming webinars.

*Requires FREE ACS ID

72

72



www.acs.org/acswebinars



ACS Webinars® does not endorse any products or services. The views expressed in this presentation are those of the presenter and do not necessarily reflect the views or policies of the American Chemical Society.

Contact ACS Webinars® at acswebinars@acs.org



Mike Russell Erik

73

73