



Challenges Scaling Up Cellulosic Biofuels for Transportation

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A Long Time Player in Cellulosic Biofuels



- **Top five registered producers of cellulosic biofuels in the U.S.**
 - 8% of all U.S. cellulosic biofuel
- **Leading developer in the space**
 - Cellulosic ethanol
 - Renewable hydrogen
- **Partnered with major energy companies to bring our cellulosic biofuels to market**



Enzyme Business: Historical relationships include:






Two Major Market Segments

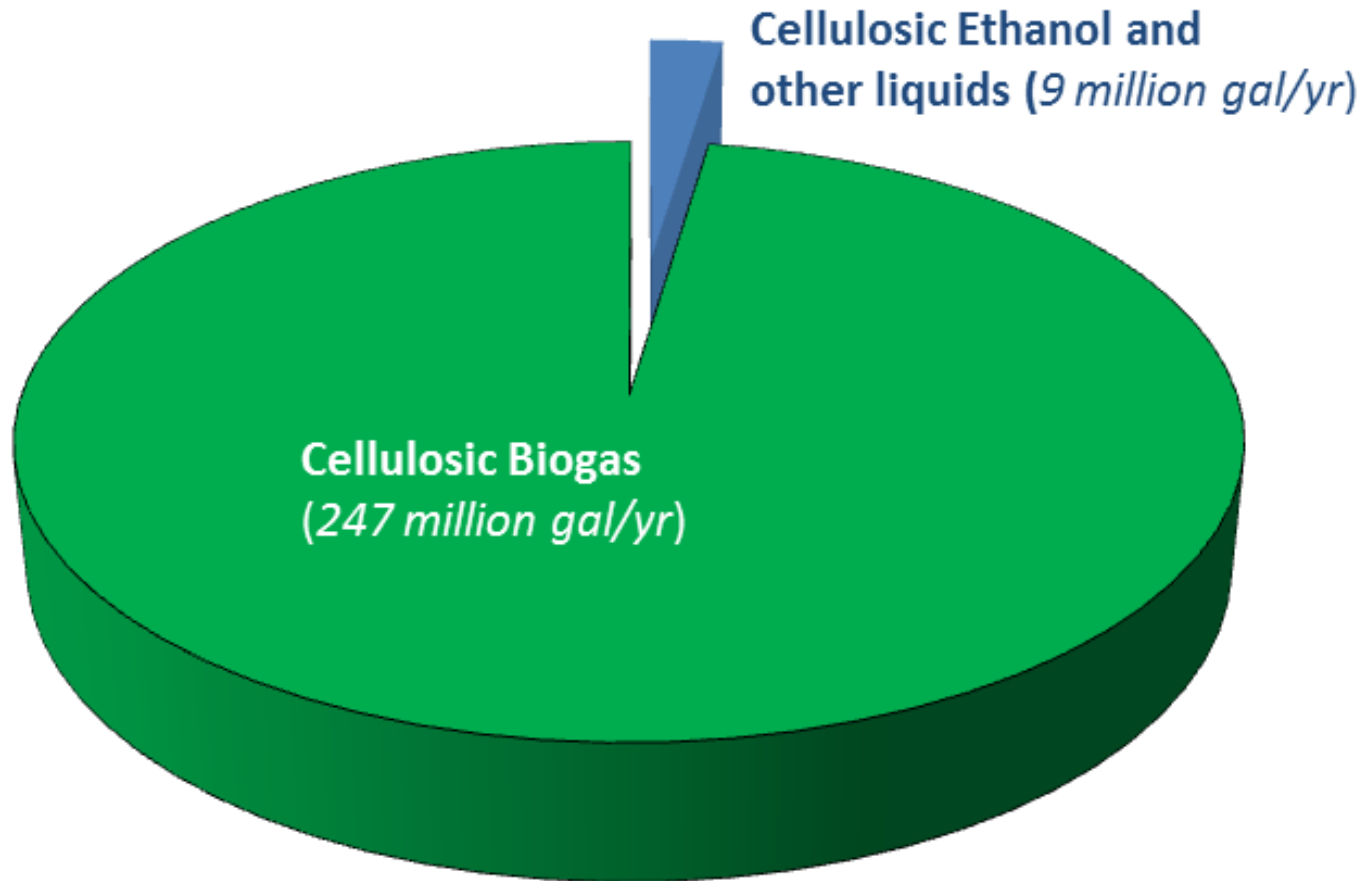


Two Major Market Segments - *Liquids*



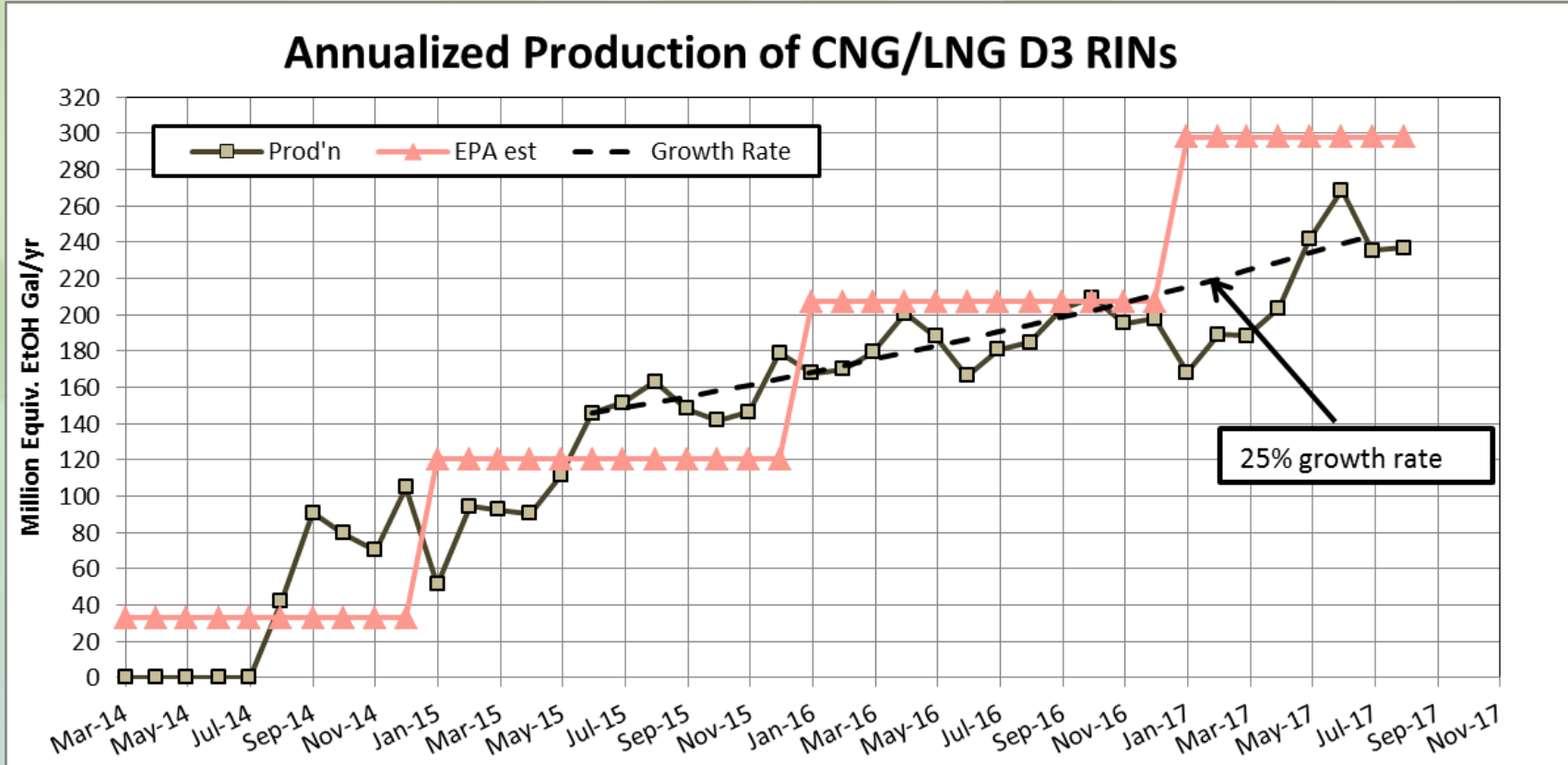
Cellulosic Ethanol and
other liquids (*9 million gal/yr*)

Two Major Market Segments - *Biogas*

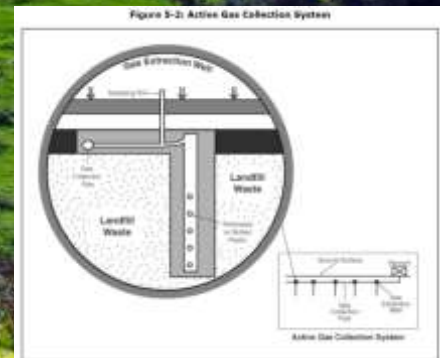


Current cellulosic biogas market: \$750 million

Growing at 20-25% per year



What is Cellulosic Biogas?



- **Biogas is:**
 - A mixture of methane, CO₂ and other gases
 - Produced by anaerobic digestion of organic matter
 - Sourced from landfills and waste digesters
 - It can be collected and purified into renewable natural gas

How is Cellulosic Biogas a Transportation Fuel?

- EPA found biogas from landfills and other sources to be cellulosic
- Transportation fuels made from most biogas now qualify as cellulosic
- First approved pathway for cellulosic biogas is to CNG for vehicles
- Other pathways (e.g. for making partially renewable gasoline) are in the queue



Challenges scaling up the biogas business?



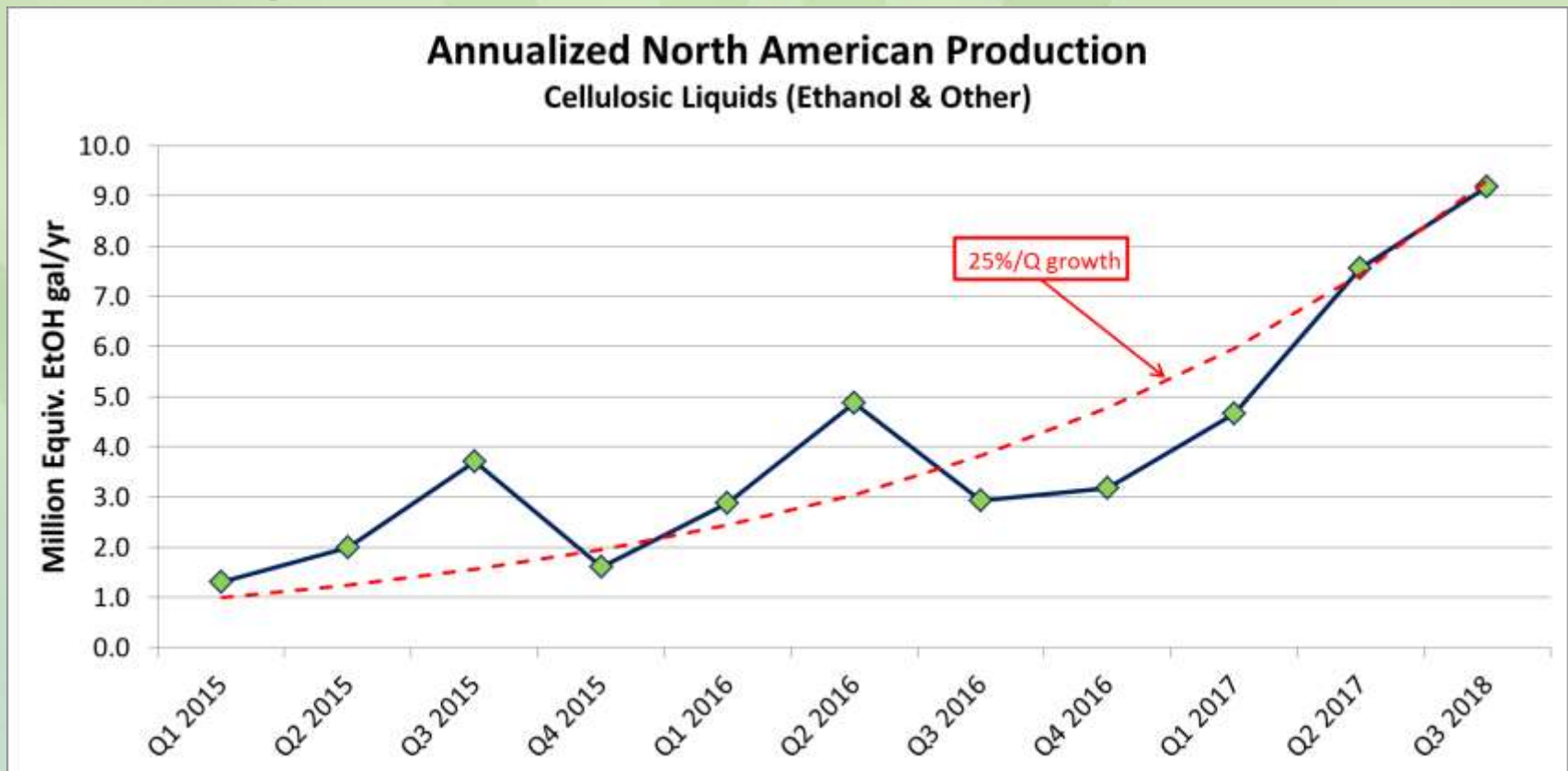
- On the face of it, the business makes money and the technology is well proven
- Tough to get long term prices for fuel credits
 - Buyers are loath to offer futures in fuel credits – *political risk*
 - Investors need to take a big hair-cut or a big market risk
- **Fundamental Challenge**: Lining up everything for a project and still delivering an acceptable risk/return to investors



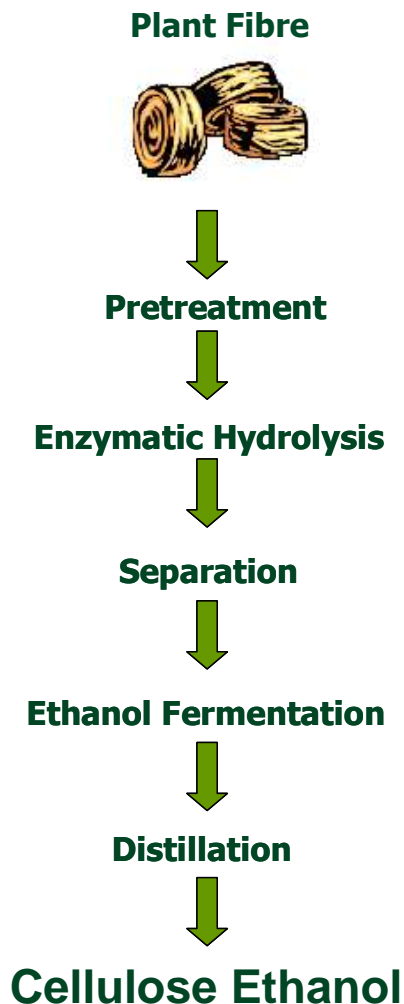
Current cellulosic liquids market:

Current cellulosic liquids market: *\$35 million*

Growing at 25% per quarter



What is the story on liquid cellulosic biofuels (*EtOH+*)



- **“Old school” developers of large integrated facilities (Gen 2.0):**
 - Poet/DSM, DuPont, Abengoa, Iogen/Raizen, Beta-Renewables and others
 - Billions of dollars spent – *Lot’s of difficulties*
- **Gen 1.5 cellulosic plants**
 - Smaller facilities integrated into corn mills
 - Numerous projects have been started-up
- **Both approaches might just be starting to hit their stride**
 - Industry wide utilization rates still <<50%

Challenges scaling up this business? - *NOW*

Plant Fibre



Pretreatment



Enzymatic Hydrolysis



Separation



Ethanol Fermentation



Distillation



Cellulose Ethanol

- Job Number One – *Demonstrate highly reliable operation*



- If multiple players deliver ...
- We could see three or more years of 25%/quarter growth

Challenges scaling up this business? - *NEXT*

Plant Fibre



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The Optimistic Scenario

- The liquids business starts to look like cellulosic biogas
 - *On the face of it, the business makes money and the technology is well proven*

...

Challenges scaling up this business? - *NEXT*

Plant Fibre



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Cellulose Ethanol

Not So Optimistic Scenario

- **Tough landscape for new plants**
 - OPEX: \$1.50/gal
 - CAPEX: Gen 2: \$6-10/gal/yr
Gen 1.5: \$3-4/gal/yr
 - Yields: 75 - 95 gal/MT
- **Job Number “Two” – Deliver better economics – especially capex**
 - *Simplify process operations*
 - *Integrate into existing operations cost effectively*
 - *Improve the yield to fuels (and co-products)*

Thank You



Challenges Scaling Up Cellulosic Biofuels

Biogas

Liquids