# Driving Towards Sustainable Mobility

## *Overview of GM's Biofuels Activities*
## *Biomass 2009*

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# 96% of Today's Vehicles Are Dependent on Petroleum

- GM's commitment to biofuels is about offering our customers a choice and
- The ability to fuel their vehicles with

  Low cost

  Renewable

  Sustainable

  Domestically Produced

  alternatives to petroleum

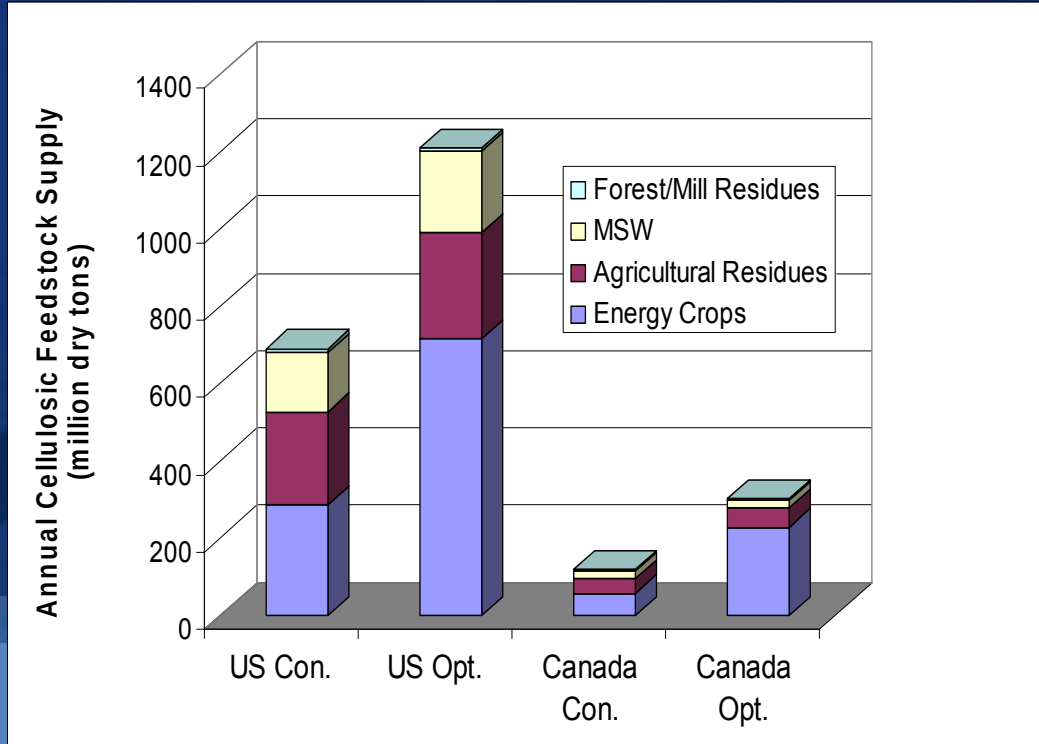
- Realizing this goal will take all of us working together

# Key Points on Biofuels

- General Motors believes biofuels, including E85 ethanol, are the most significant near-term solution to offset rising vehicle energy demands and reduce greenhouse gas emissions
- Next-generation biofuels …
  - Provide a clean, renewable alternative to petroleum
  - Are fast approaching with cellulosic ethanol nearing commercialization in the 2010 – 2012 timeframe
- Sustainable biofuels made from non-grain sources could offset up to 35 percent of future vehicle energy demand by 2030, but the infrastructure needs to be in place for commercialization to be realized
- Making E85 a viable alternative fuel requires significant growth in the number of stations offering the fuel and pricing that accounts for the 20-25 percent reduction in fuel economy
- Feedstocks such as woody biomass, agricultural waste and purposefully grown energy crops are the most abundant and sustainable sources for next-generation biofuels

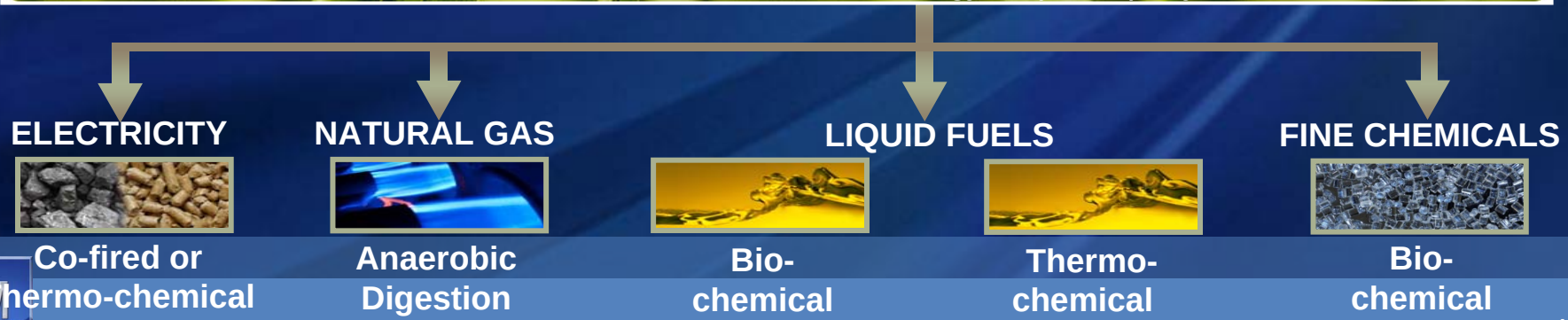
# GM's Own Internal Study Closely Confirms Biomass Potential

- GM's University of Toronto study estimates the biomass potential at 0.625 – 1.2 B tons enough to produce 50 – 134 B gal of ethanol
- US DOE billion ton study estimates the annual biomass potential at 1.33 B tons by 2030 with an ethanol potential of 97.5 B gallons
- Also not a lack of biomass issue – many sources including waste materials but purposely grown energy crops are critical
- It is a timing issue - based on technology improvements and implementation and economics



# Low Cost Biomass Will Be Critical to Future Energy Production Regardless of Fuel Carrier – Powertrain System

- Biomass is a feedstock for chemicals, electricity, and natural gas - not just liquid fuels
- It is essential to successfully grow energy crops at large scale
- Biotechnology improvements and agronomics are both key to improving yields



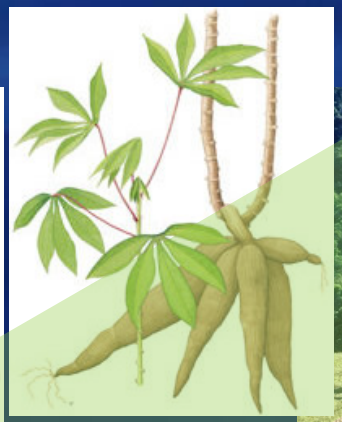
# Biofuels Are Moving up Technology Roadmap

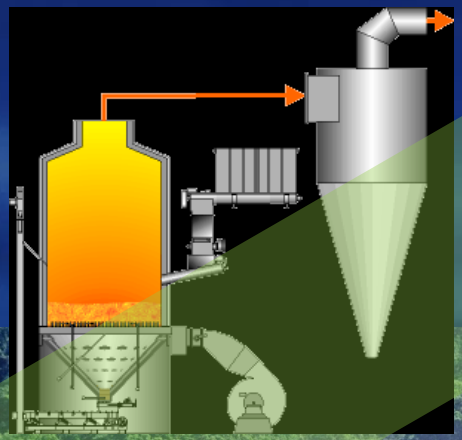
Synthetic Biorefinery

Gasification

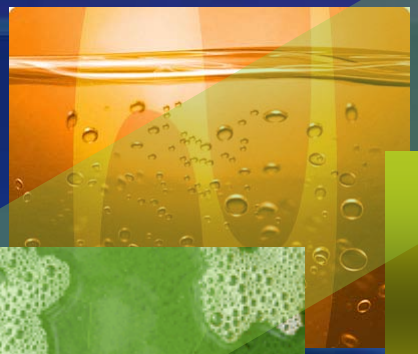
Cassava

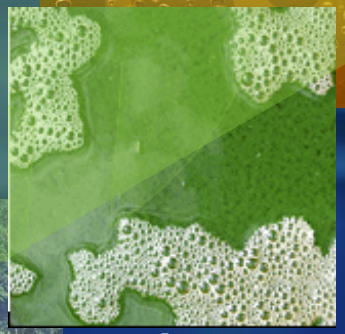
Corn





Cellulosic Bioethanol





Algae

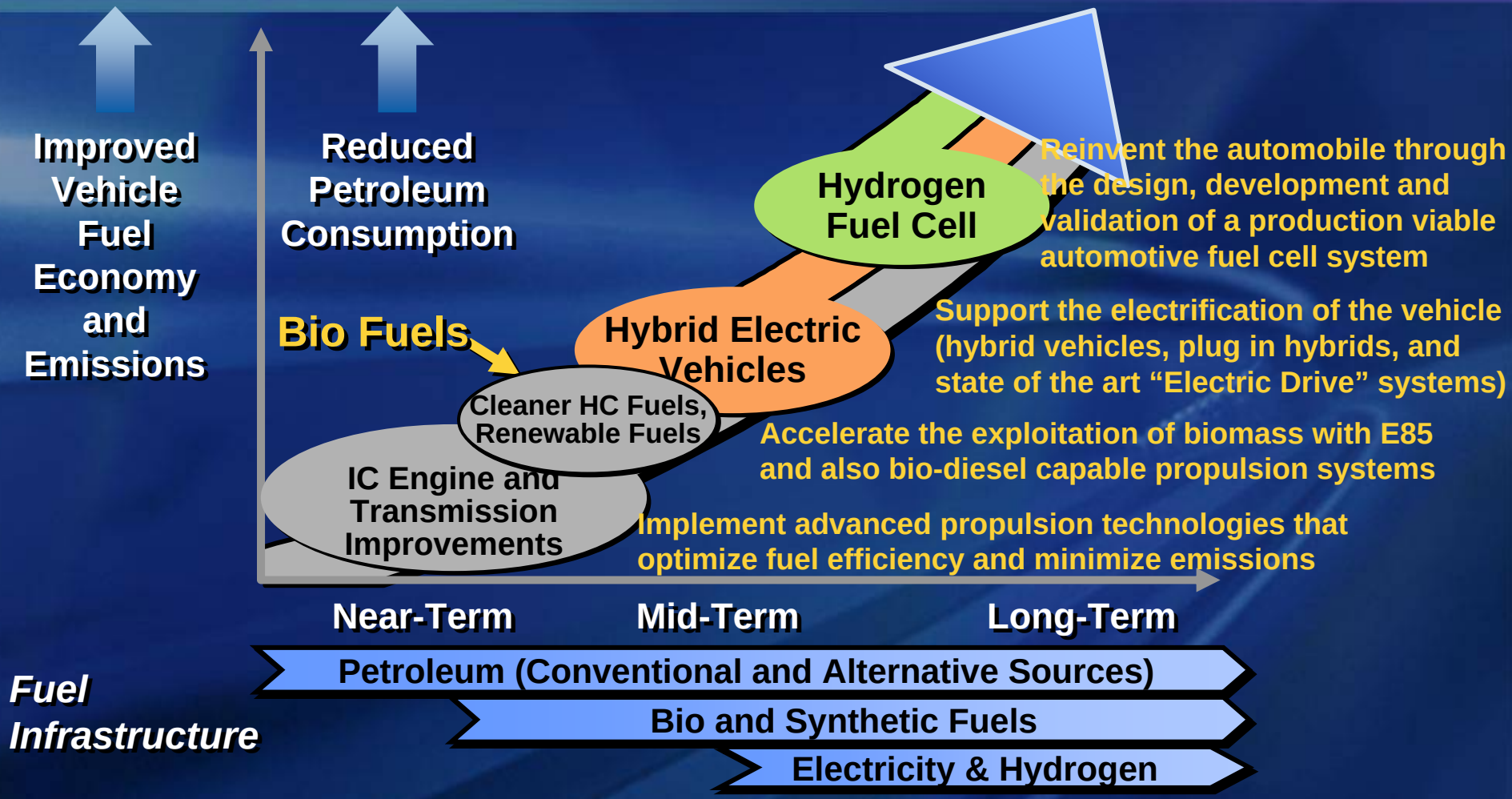
Direct Synthesis?

***And we have only just begun …***

| 1st Generation | "Gen 1.5" | 2nd Generation | 3rd Gen | 4th Gen |
|---|---|---|---|---|
| Sugarcane | Sweet Sorghum | Energy Cane | Algae | Microbes convert CO2 directly to fuel |
| Corn (Starches) | Cassava | Grasses, Wood | "Green" Hydrocarbons | |
| Oil seeds | Jatropha | Waste | | |

# Advanced Propulsion Technology Strategy

**Promote and execute a "Blended Energy Carrier Strategy" that incorporates the use of liquid fuels, electricity, and hydrogen**



# What is GM Doing

- Vehicle
  - GM has built 3.5 M FFVs of 7 M on the road in the US
    - In Brazil, FlexPower accounts for 95% of sales
    - In Europe, Saab leads the environment-friendly car segment with the BioPower 9-3 and 9-5, accounting for >80% of Saab new vehicle sales
  - GM is offering 20 Flex Fuel models for 2009
  - GM is committed to having 50% of our models E85 capable by 2012
- Infrastructure
  - Partnering to increase the availability of E85 by promoting the expansion of E85 stations - NGA partnership a key step
  - Currently, fewer than 1,900 fueling stations in the US, or a little more than 1 percent, offer E85, and more than 60 percent of those are concentrated in Midwest states
- Technology
  - Working with the best researchers in this area
    - Consortiums (C2B2, ISU, and SD NSF, etc.)
    - Universities (MSU, MTU, U of T, and Ben Gurion, etc.)
    - Research Centers (JBEI, GLBRC, etc.)
  - Partnering with the best companies (cutting edge technologies) around the globe (Mascoma, Coskata, etc.)

# Completion of the I-65 Corridor

- I-65 is the first national, cross-country biofuels corridor with no gaps in E85 ethanol availability from Lake Michigan to the Gulf of Mexico
- GM partnered with States of Indiana, Alabama, Tennessee, and Kentucky as well as DOE, Clean Cities, and the many other organizations on completion of this great undertaking
- As a result of work over the last 2 years, motorists along the I-65 corridor (886 miles) are never more than a quarter of a tank away from an E85 pump
- More examples like this one are needed in the United States as we move to next generation ethanol

# GM R&D Direct Biofuels Contracts

- GM R&D is directly funding biofuels research and technology development globally to further advantage ethanol production

| Ben-Gurion | Michigan Tech | Michigan State | University of Toronto |
|---|---|---|---|
| ▪ Assess growing energy crops (sugar beets, sweet potato, sorghum) in the Negev/Arava regions of Israel using brackish water<br>▪ Determine plants to be used for economical ethanol production<br>▪ Promising research applicable to China and other regions | ▪ Focus on woody biomass<br>▪ Optimization of pretreatment and use of epimerases to obtain improved yields<br>▪ Development of microbial-based, value-added co- product | ▪ Logistics of feedstock transport and preprocessing<br>▪ Technical and economic feasibility of the regional bioprocessing centers for pretreating biomass for the biorefinery<br>▪ Animal feed production with high protein and high digestibility feeds | ▪ Economics of energy crop supply and biodiesel production<br>▪ Potential production costs of biobased transportation fuels<br>▪ Examining the "preferred" use of biomass feedstocks |
| ▪ Energy crops that can be grown on marginal land<br>▪ Develop cost effective ethanol production for semi arid regions | ▪ Potential for woody feedstocks<br>▪ Reduce cost of ethanol production through biorefinery approach | ▪ Streamline collection and preprocessing of biomass for reduced cost and overall environmental impact | ▪ Economics of biodiesel production and best use of biomass |

# GM Participation in Biofuel Consortiums

**GM serves on the Industrial Advisory Boards of several consortia directed at ethanol development**

- DOE Joint Biofuel Energy Institute
  - Concentrate on "model" crops of rice and *Arabidopsis and* exploring microbial-based synthesis of fuels beyond ethanol
- DOE Great Lakes Bioenergy Research Center (U of W and MSU)
  - Studying effectiveness of different plants; exploring plant fiber breakdown, increasing plant production of starches and oils that are easily converted into fuels
  - Focus on environmental and socioeconomic implications of a biofuels economy
- Colorado Consortium for Biofuels and Bioproducts
  - Development of new technologies for future commercialization of integrated, sustainable biorefining and biofuels processing
- Iowa State University Center for Biobased Products
  - Analyze economic discontinuities in food, feed and fiber industries resulting from increased use of agricultural crops for biobased products
- South Dakota National Science Foundation Center for BioEnergy Research and Development
  - Six university sites and over 30 companies - focus areas including feedstock agronomy, breeding, genomics, biomass processing, and LCA

coskata

MASCOMA

- GM is committed to the rapid commercialization of “The Next Generation of Ethanol”
- GM has announced strategic alliances with two leading cellulosic ethanol start-ups, Coskata and Mascoma, that cover the biothermal and biochemical spectrum in advanced biofuel technology
- Partnership is about accelerating putting next generation of cellulosic ethanol on the market

# *Feedstock Flexible Ethanol Is An Answer To Many of Today's Problems*

## Problem

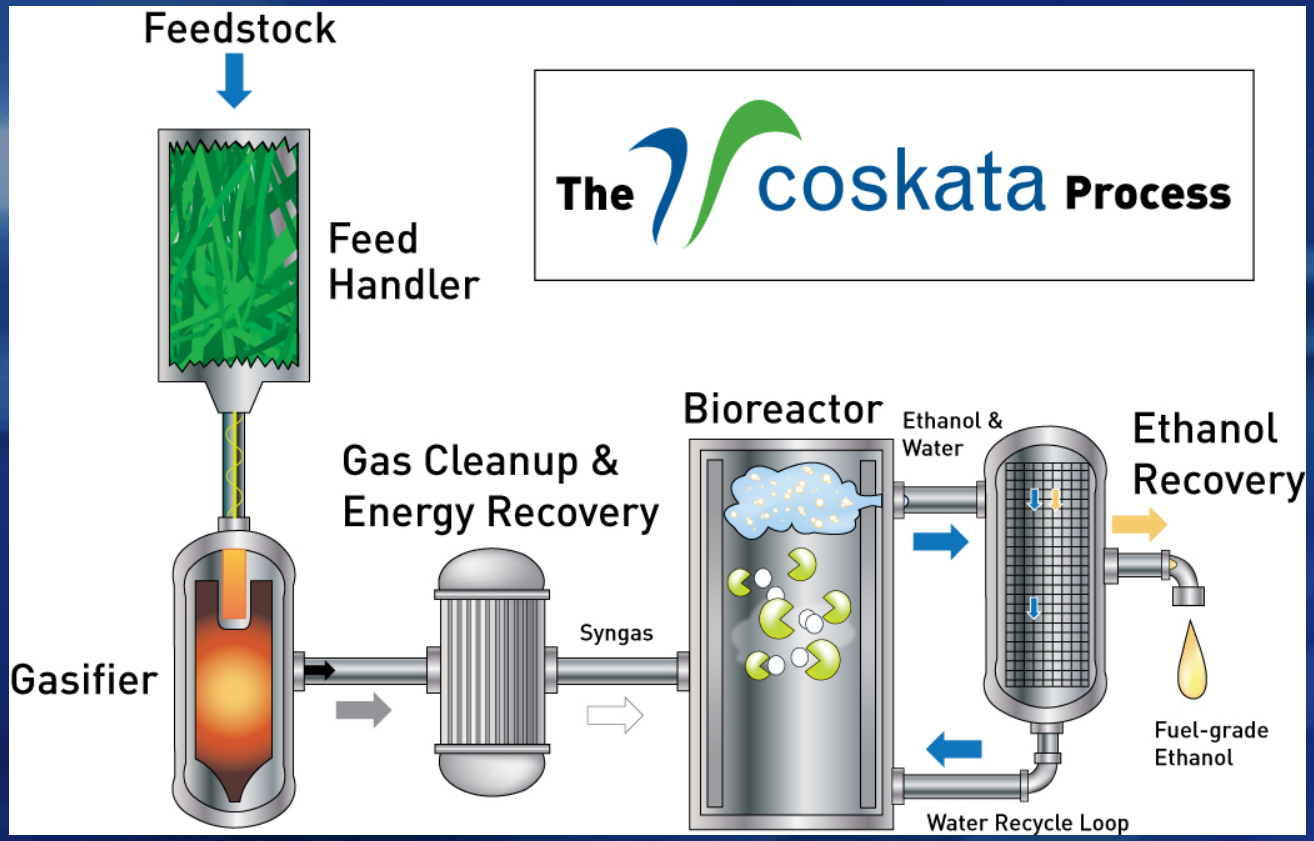
- Growing dependence on oil, over half from unstable countries
- Worst economic crisis since the great depression
- Threats to climate change and water supply

## Solution

- Fuel energy security by replacing as much as 30% of our global dependence on oil
- Fuel economic growth with new infrastructure and "green" jobs
- Fuel environmental sustainability with 60-90% less GHG's and half the water usage

**Feedstock Flexible Ethanol Technologies are ready to make a difference today**

# Coskata's Leading Feedstock Flexible Ethanol Process




**Three Step Process is efficient, affordable, and feedstock flexible:**

1. **Incoming material is converted into a synthesis gas by gasification**
2. **The synthesis gas is fermented to ethanol using bacteria**
3. **Ethanol is separated and recovered using membrane technology**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# Coskata's Technology: Flexible and Affordable

- Able to use multiple non-food based products around the globe For example…

Wood Waste

Grasses/Energy Crops

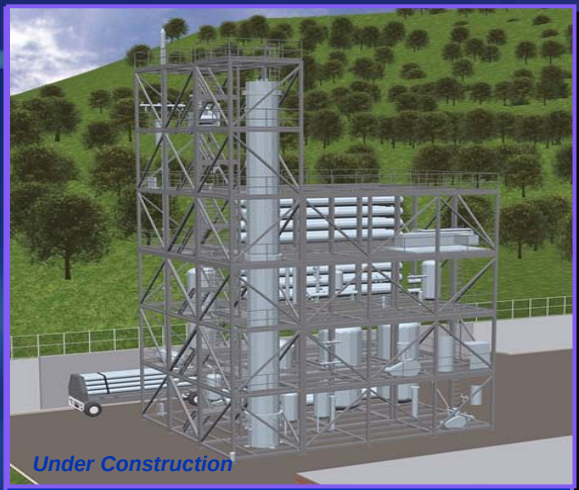
Municipal and Industrial Wastes

- Will produce ethanol that will be competitive with gasoline, unsubsidized in the long term
  - Yields over 100 gal/dry ton biomass of fuel grade ethanol
  - Returns up to 7.7 times as much fossil energy as what is used to produce the fuel
  - Uses less than one gallon of fresh water per gallon of ethanol
  - Reduces green house gas emissions by up to 96%

# Coskata Is Proceeding to Commercial Scale

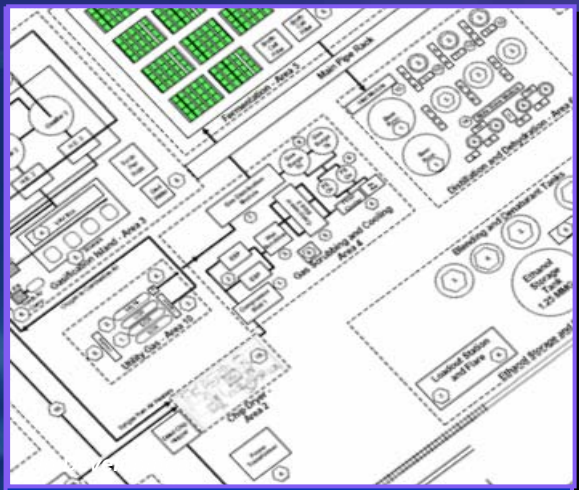
**Horizon (Q1 2008)**
***Integrated Processing***
**Warrenville, IL**

- **Integrated processing system with methane thermal reformer, multiple bioreactor designs, and distillation**




**Lighthouse (2009)**
***Commercial Demonstration***
**Madison, Pennsylvania**

- **Minimum engineering scale (linear scale-up to commercial production)**
- **Front-end biomass gasifier**
- **Will test multiple commercial-scale bioreactor and separations designs**

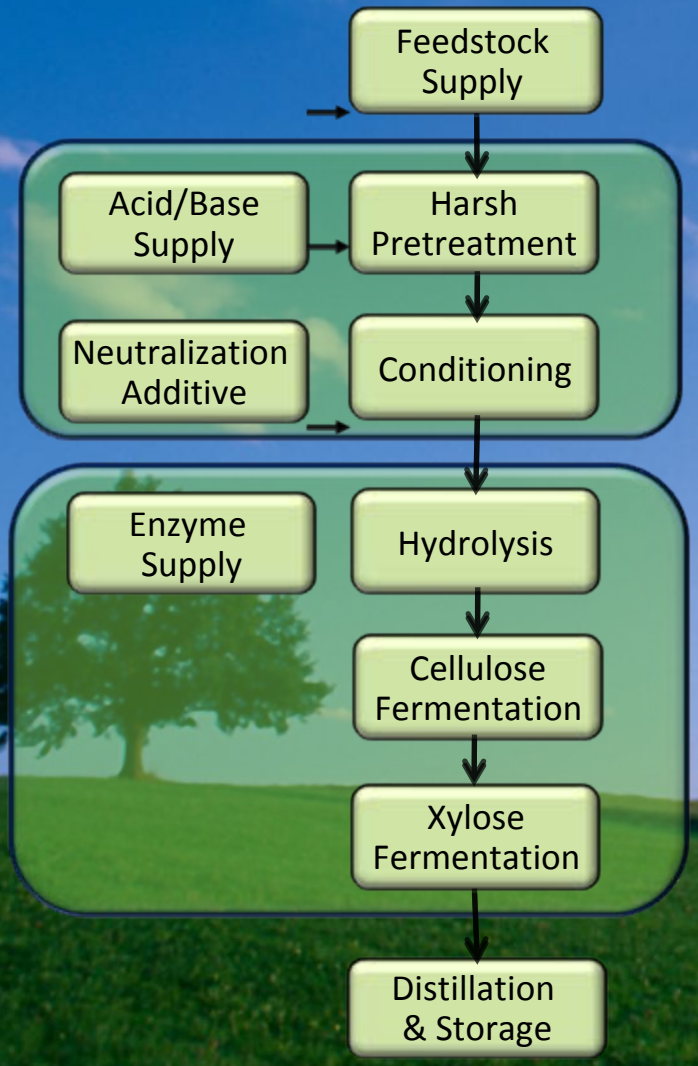


**Flagship -**
***Commercial Facility***
**Location: Southeast U.S.**

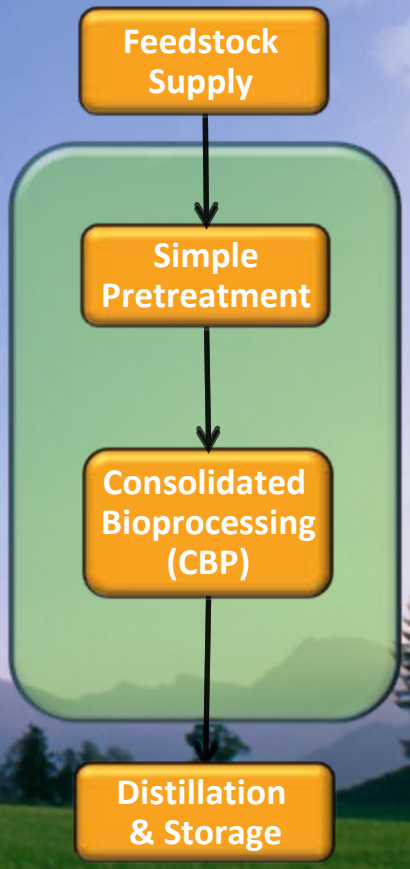
- **50-60 MM Gallons / yr**
- **Multiple gasifiers that process ~1500 dry tons/day of biomass**
- **Only fuel-grade ethanol production**
- **Startup of facility contingent on closing financing**

# Mascoma's Advanced Technology, Simplified Process

## Traditional Approach: Sequential Processing




## Mascoma Approach: Consolidated Bioprocessing




MASCOMA

# Mascoma's Path to Commercialization

**R&D Labs**

- Developing robust CBP organisms and process to cost effectively convert non-food biomass into cellulosic ethanol
- Focusing on proprietary technology to integrate best in class pretreatment process with conversion technology minimizing operating and capital cost

**Rome, NY Pilot Plant**

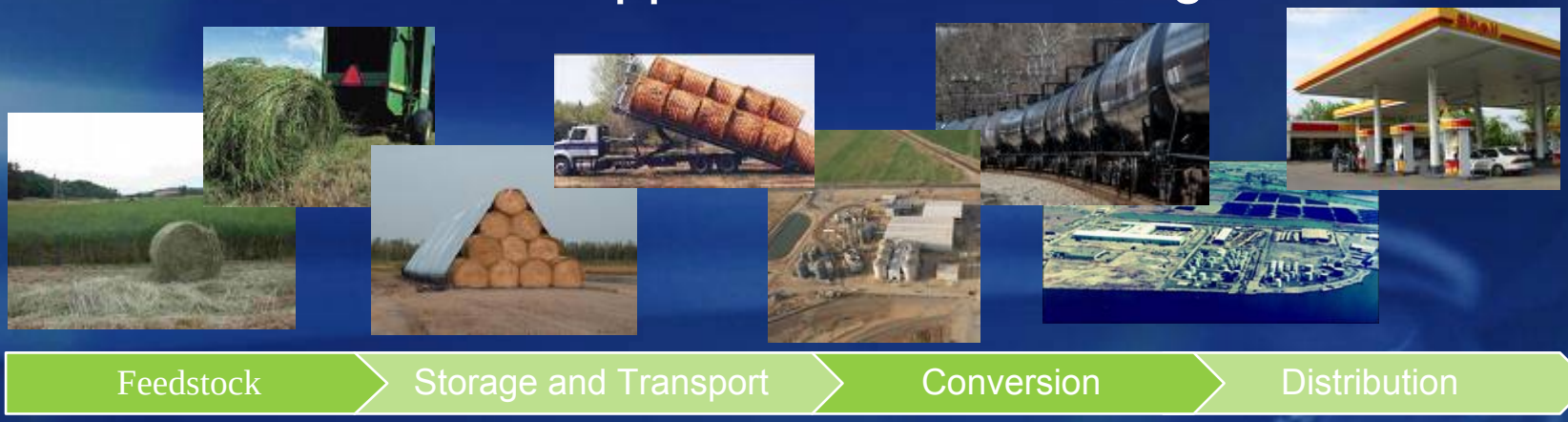
- One of largest cellulosic ethanol facilities currently under operation with a production capacity of up to 200,000 gallons/year
- Capable of running on numerous biomass feedstocks, including wood chips, grasses, sugar cane bagasse, and corn stover
- Drove GM car on cellulosic ethanol produced at Rome plant in Dec 2008

**MI Commercial Plant**

- Received over $40MM from Department of Energy and the State of MI
- Located in Chippewa County in the Upper Peninsula
- Designed to produce 40MM gallons/year using hardwoods as the primary feedstock

# GM Sandia 90-Billion Gallon Biofuel Deployment Study

Joint project conducted by GM and Sandia National Laboratories is the first true value-chain approach to future large-scale biofuels




Can Large-Scale Biofuels Provide a Real and Sustainable Solution to Reducing Petroleum Dependence?

1. What must happen to grow ethanol production to 90B gal by 2030?
2. What is required for cellulosic ethanol to be cost competitive with gasoline?
3. What are the greenhouse gas, energy, and water footprints associated with this level of ethanol production?
4. What risks could impact cellulosic ethanol's production and competitiveness goals and how can we mitigate these?

# Significance: GM's Biofuels Partnerships

- Our biofuels partnerships have are a key part of GM's leadership in energy diversity
  - Has helped to drive the industry forward
  - Enabled access to cutting edge research/ technology and the exchange of information
  - Provided opportunity to identify and benchmark synergies with other technologies and impact on GM
- We continue to look for ways to partner and move the industry forward
- There are no clear "winners" to date
  - We strongly believe in the companies with which we have partnered
  - Continue to believe that it will take all of the cutting edge technologies currently being developed to reach our goal of 36 B gal by 2022 and beyond

# Summary

- The next 2-3 years is a crucial time for advanced biofuels as pilot/demo plants become fully operational and first commercial plants are constructed and launched
- Continued government support (mandates & incentives) are crucial to fully launch the biofuel ramp-up – commercial competitiveness takes over
- Government, industry and academic partnerships will be needed to support the growth of a sustainable biofuels industry
- Integration of all steps in the value chain from crop development, production, harvest, and storage to fuel production, distribution, and use in vehicles is needed
- GM's biofuels partnerships have strengthened GM as the automotive leader in biofuels

# Gas-Friendly to Gas-Free

FUEL EFFICIENCY

E85 ETHANOL

HYBRID

ELECTRIC

FUEL CELL

GM
Thank You for Your Attention