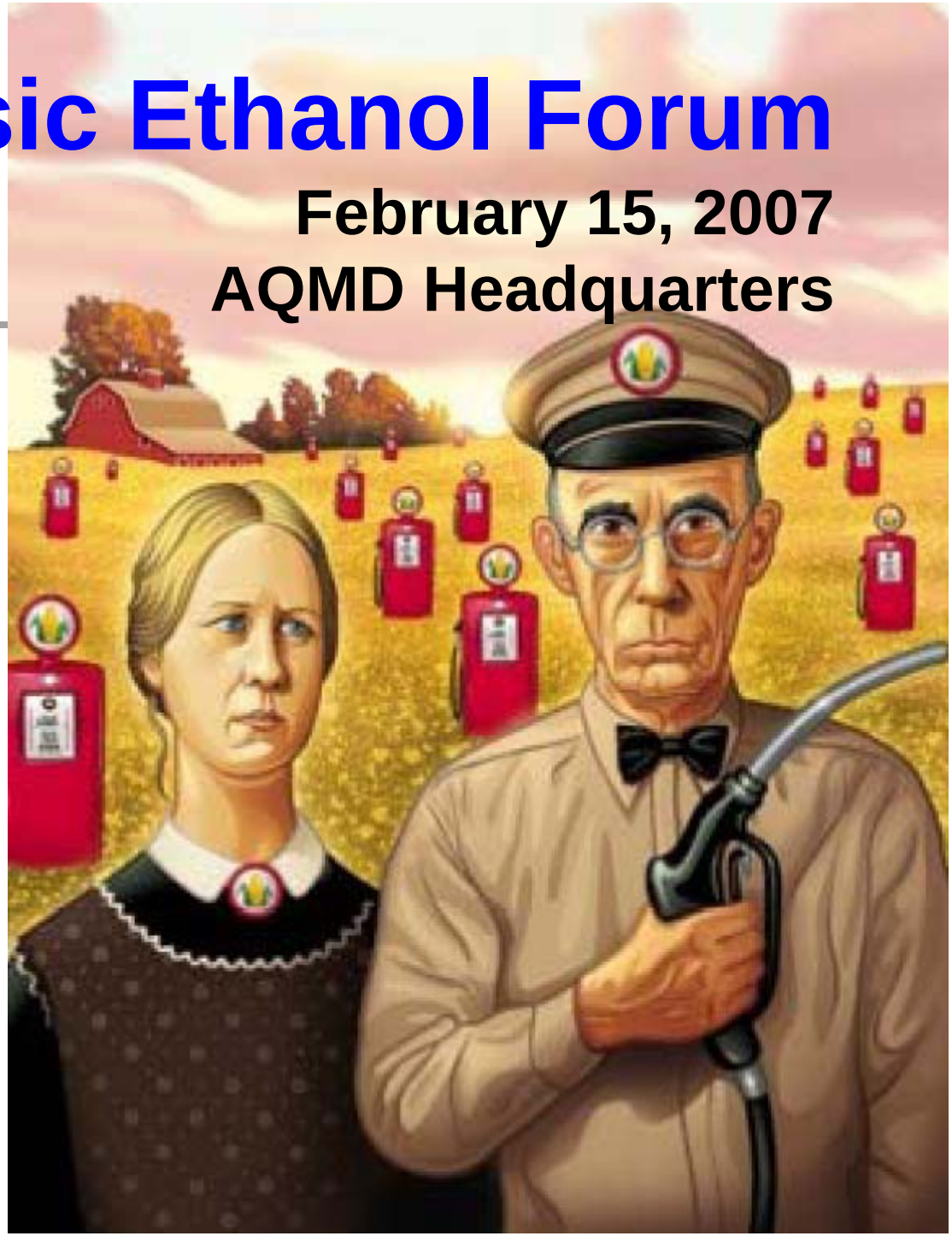
Cellulosic Ethanol Forum

February 15, 2007
AQMD Headquarters



Overview of Air Quality and the Potential Role for Cellulosic Ethanol

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Clean Fuels Officer
South Coast AQMD

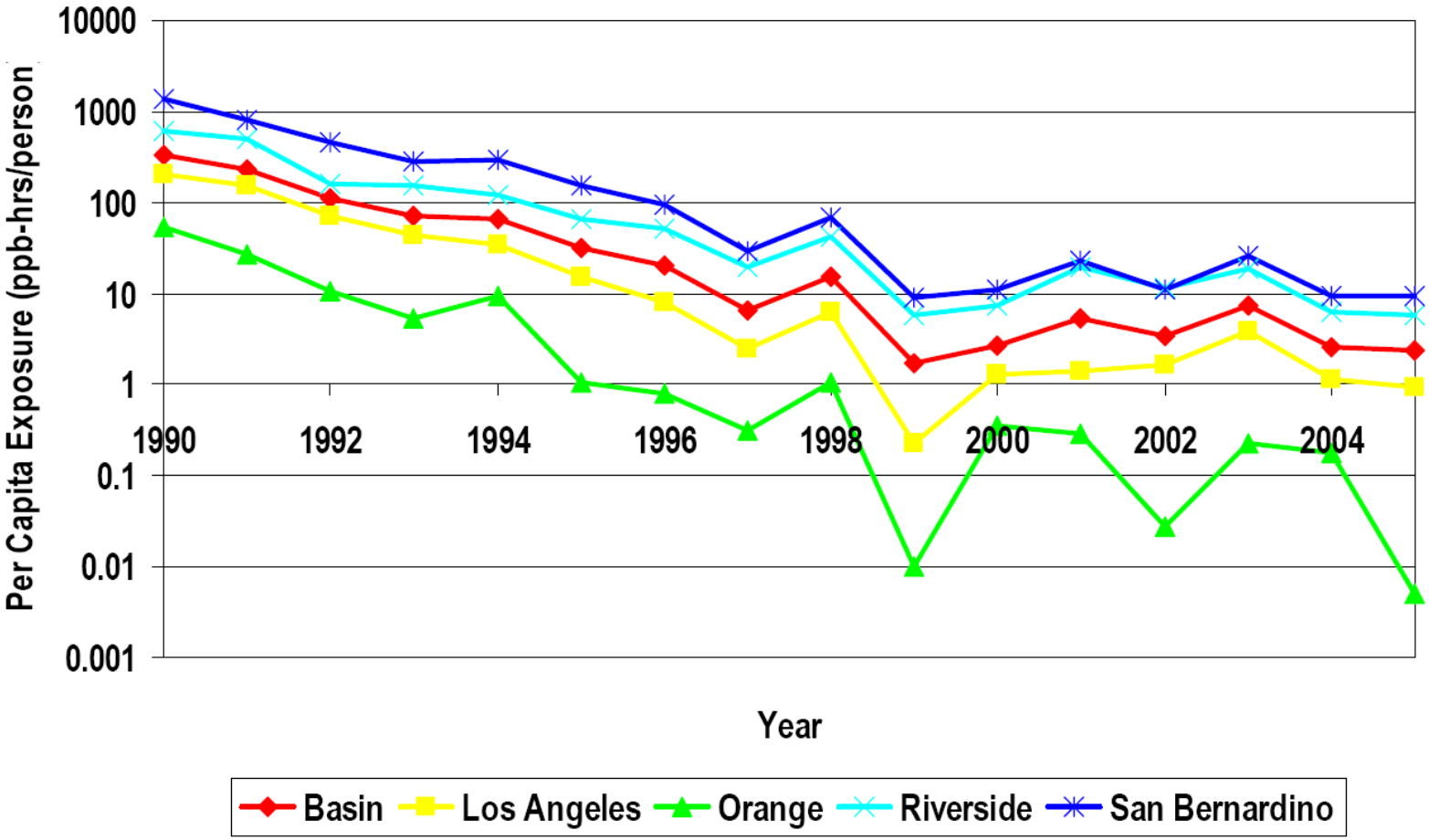
Focus of this Meeting:

- Cellulosic Feedstocks
  - switchgrass, corn stover, poplar, and others
- Any conversion Technology
  - fermentation / enzyme based
  - synthesis gas based (i.e., CO / H_2 mixtures…)
  - other technologies / biological systems
- Identify current status of technology
- Identify opportunities for collaboration
- Identify key areas for policy support / clarification
- Expedite ozone, PM and GHG mitigation efforts

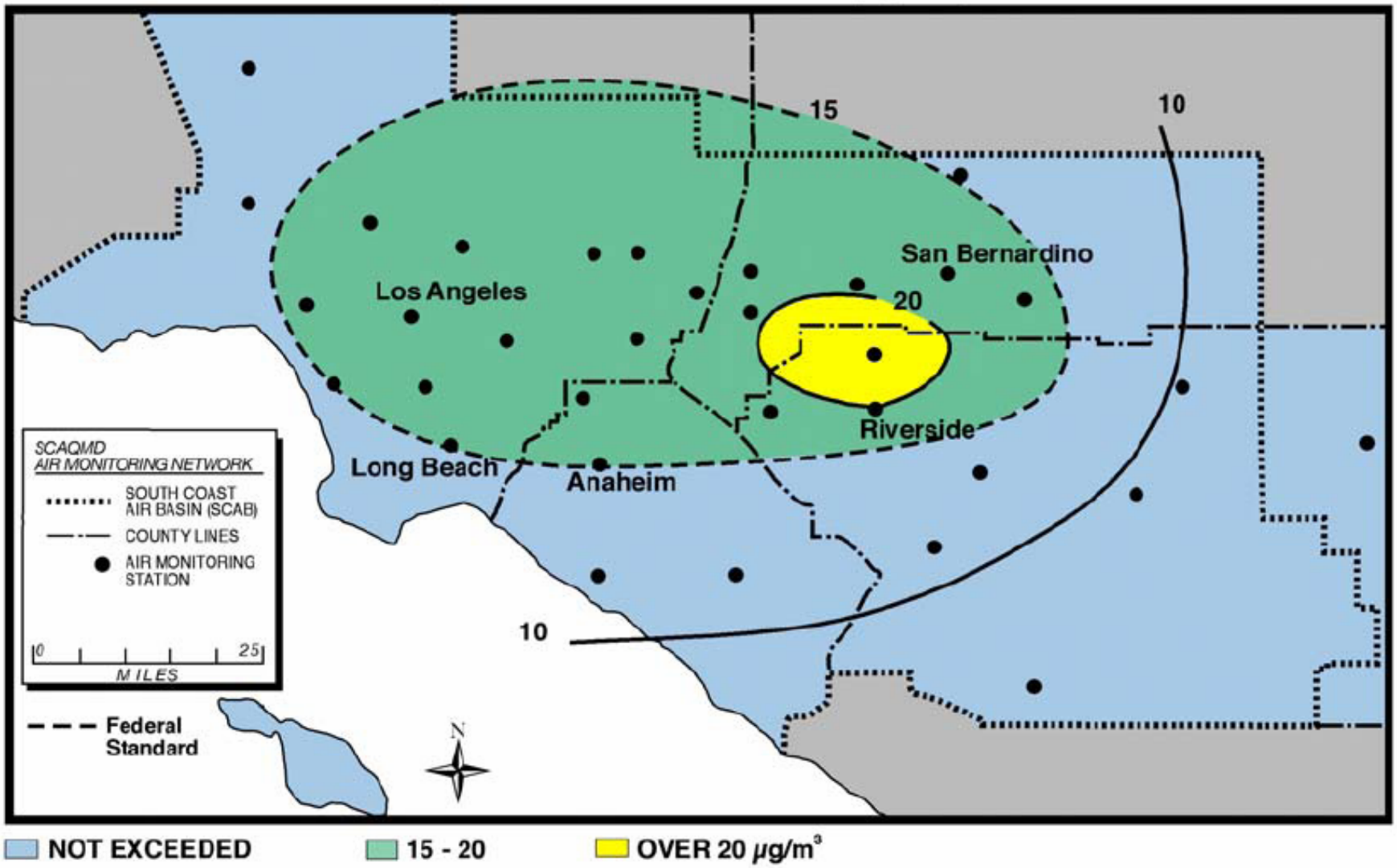
Some Key Questions

1) **What is the status of current cellulosic conversion technology?**
2) **What key constraints such as acreage, water, topsoil, nutrient cycles, etc. exist on various cellulosic feedstocks?**
3) **What supply volume, cost and timing expectations are appropriate for cellulosic ethanol?**
4) **How would you assess the potential of other biomass-derived alcohols such as butanol to supplement cellulosic ethanol production**?
5) **What is your assessment of synthesis gas-based technologies which potentially open up a wider array of feedstocks and other alcohol and related fuel products?**
6) **What scale of RDD& D funding support is needed to achieve a 35 B RFS by 2017?**

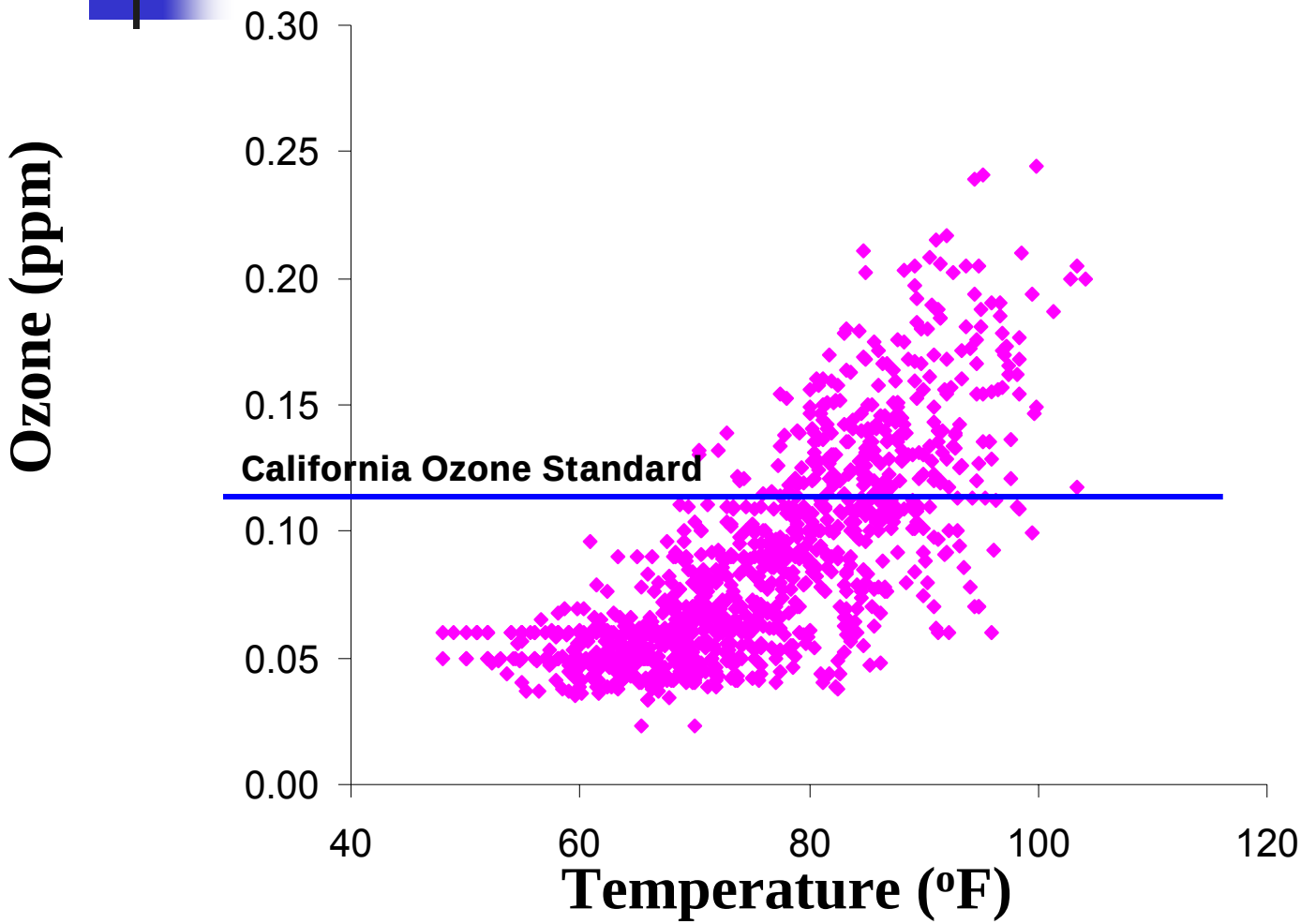
Per Capita Ozone Exposure Above the Federal 8-Hour Standard



2005 Area in Violation of Federal PM2.5 Standard



Hotter Days Lead To Higher Emissions And More Smog



Los Angeles Ozone Levels (1995-1998)

Source: California Environmental Protection Agency

Federal Ethanol Policy

- Current RFS of 7.5 Billion by 2012
  - Probably already exceeded by end of 2007…
- The 2005 federal energy bill requires refiners to use a minimum of 250 million gallons of cellulosic fuel a year beginning in 2013.
- **President's SOTU goal**:
  - 35 B gallon ethanol RFS
- $42 B in subsidies from 1995 to 2004

Cellulosic Ethanol Can Help Address Petroleum Dependency + GHG Concerns

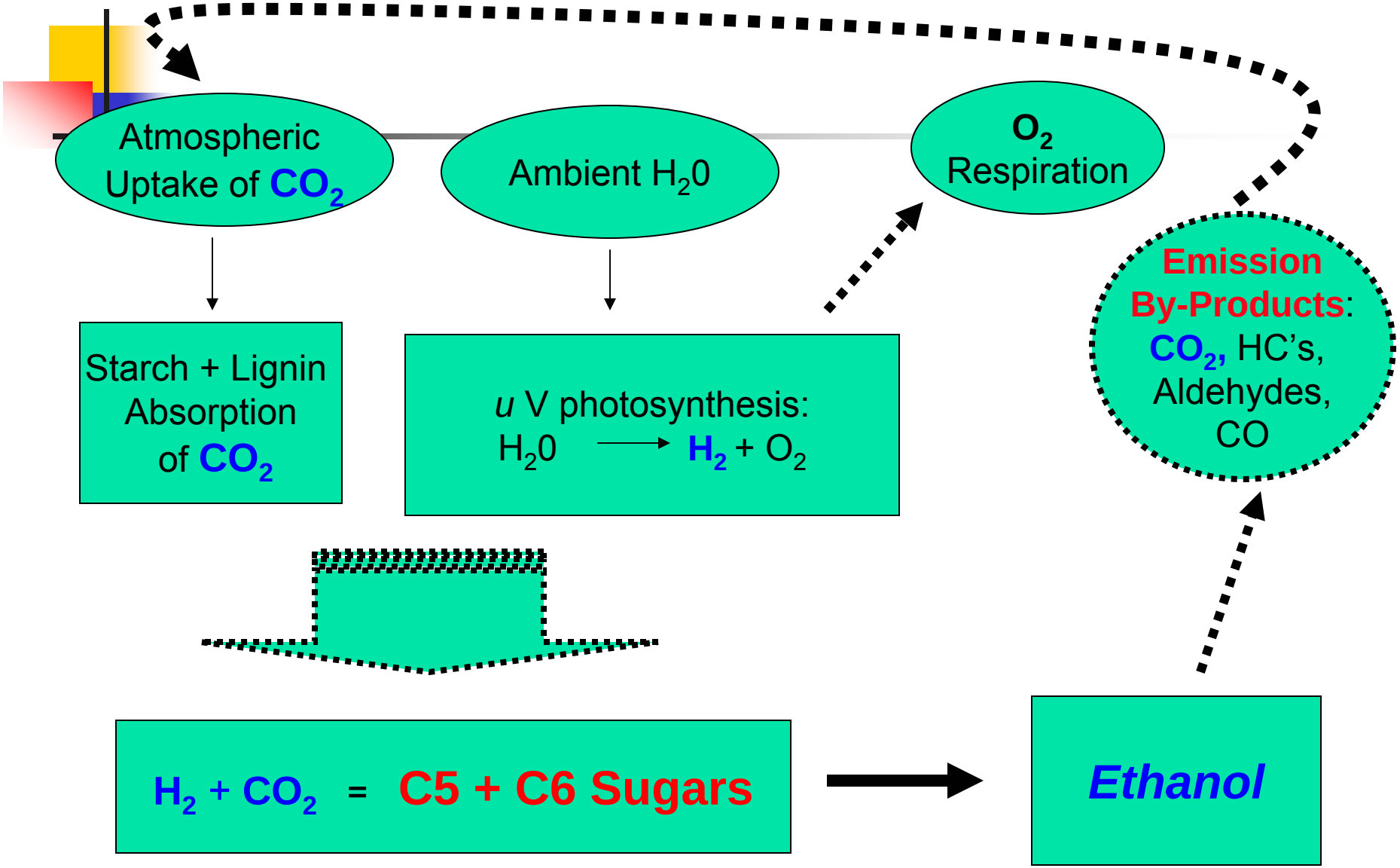
- **AB 2076 Goals**
  - Reduce Petroleum use 15% by 2020
  - Increase **AF*** use 20% by 2020
  - Increase **AF** use 30% by 2030
- **AB 1493 GHG emission standards**
  - 30% by MY 2016
  - Ethanol "Fuel Adjustment Factor" of 26%
  - Currently under litigation
- **Executive Order S-03-05: GHG Reduction Targets**
  - Reduce to 1990 levels by 2020 (≈ 25%)

AF = Alternative Fuels

More Recent CA Initiatives

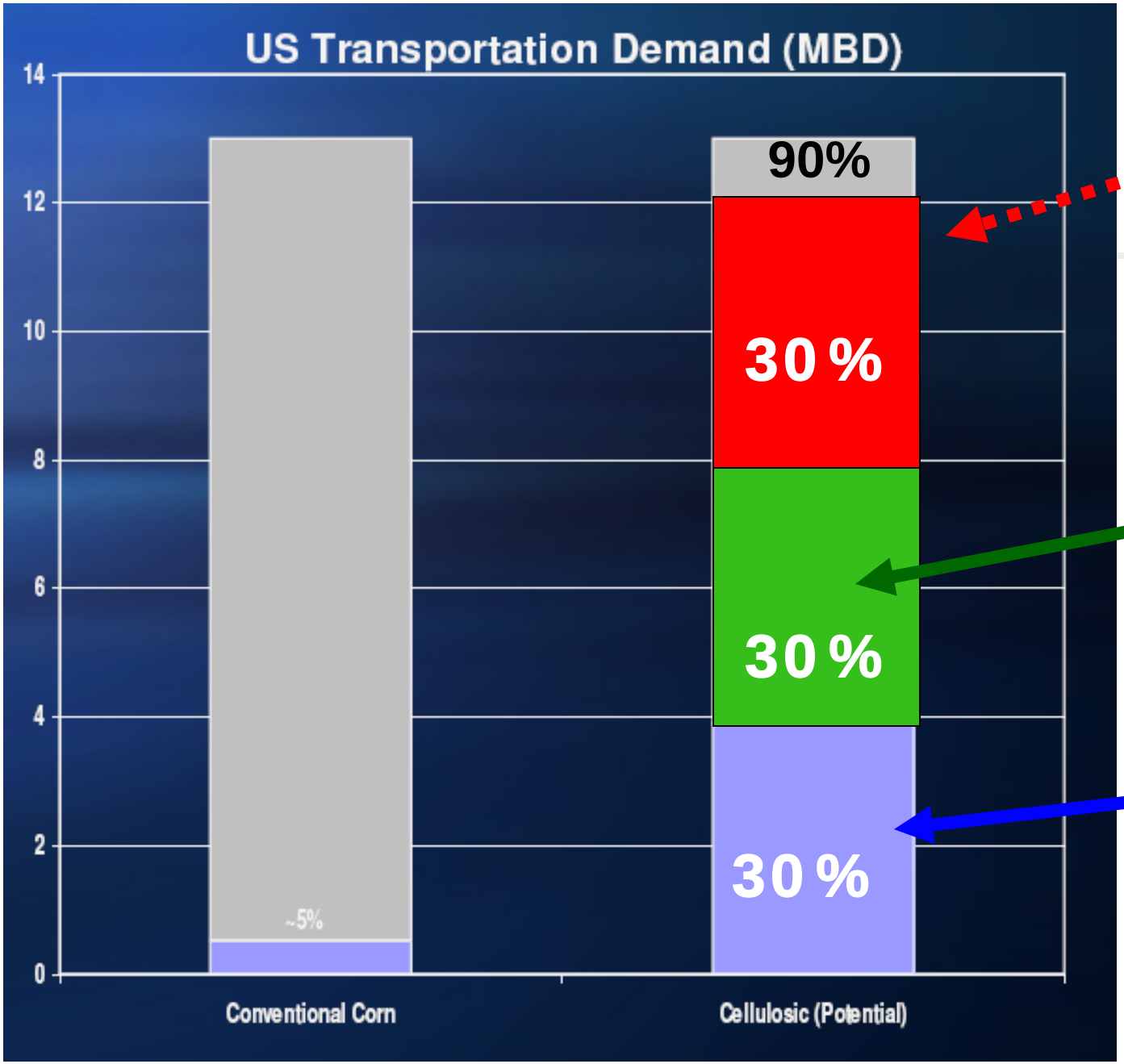
- **AB 32 Global Warming Solutions Act**
  - mandate to achieve GHG reductions from all CA sources
- **AB 1007 Joint ARB / CEC Alternative Fuel Plan under development**
- **Governor's Exec. Order S-01-07 for a Low Carbon Fuel Standard:**
  - 10% reduction in fuel carbon intensity by 2020
  - Adjusted for life cycle GHG emissions?
  - To be adopted by ARB by end of 2008

Ethanol from Cellulose: Net CO_2 Benefits



Imagine if All Vehicles Had:

- Hybrid electric drive trains
- Plug-in capability
- Renewable fuel flexibility (e.g., E-85 FFV's)
- Recharged solely with renewable power
  - Wind, Solar, etc.
- **Near zero net added carbon per mile**
- Liquid fuel utility
- **Agility** to run on $10-15 / gal. gasoline if needed



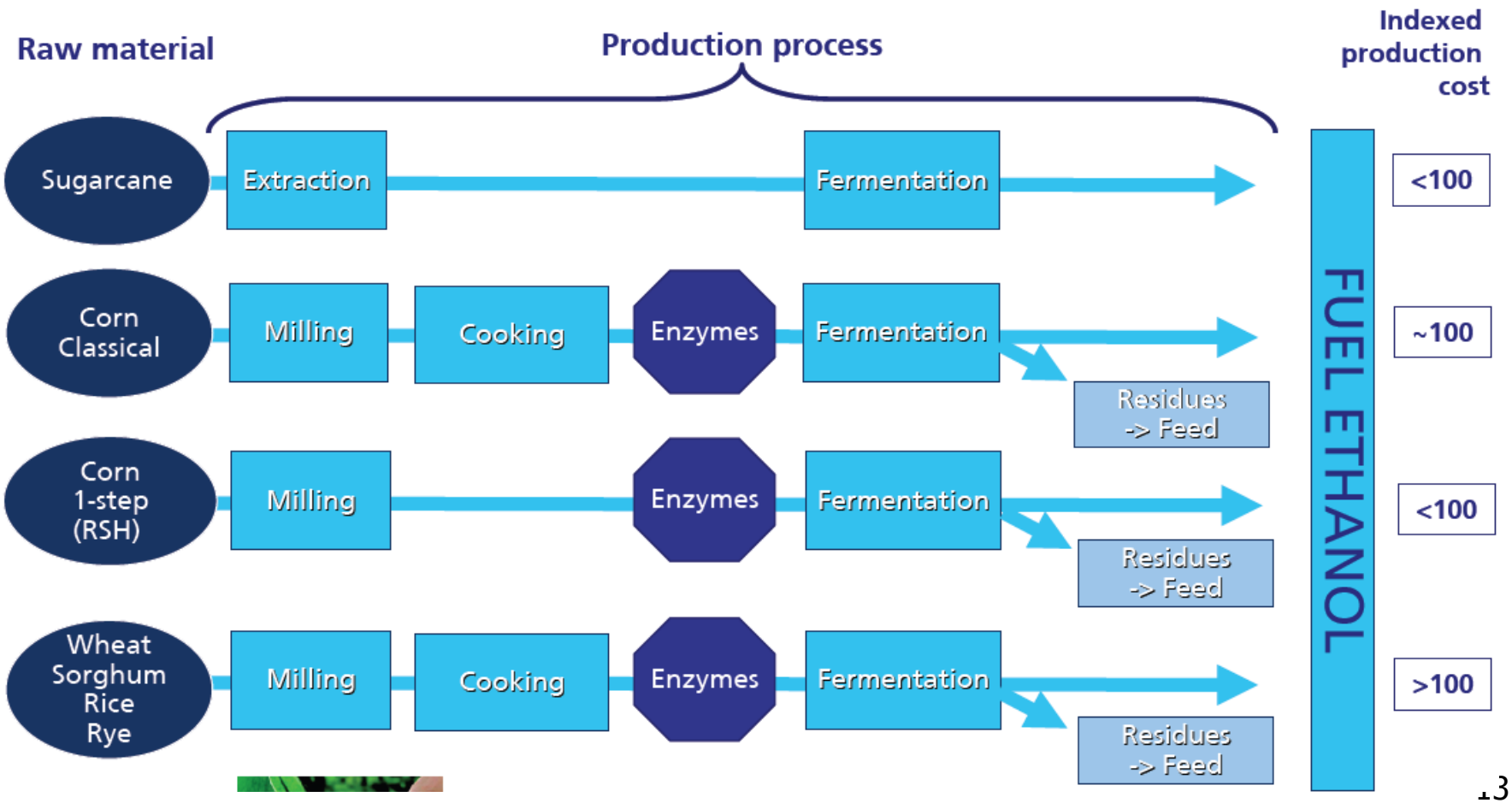
Diversion to Renewable Electricity with Plug-in Technology

2 x Fuel Economy Increase with Aggressive Hybrid Drivetrains

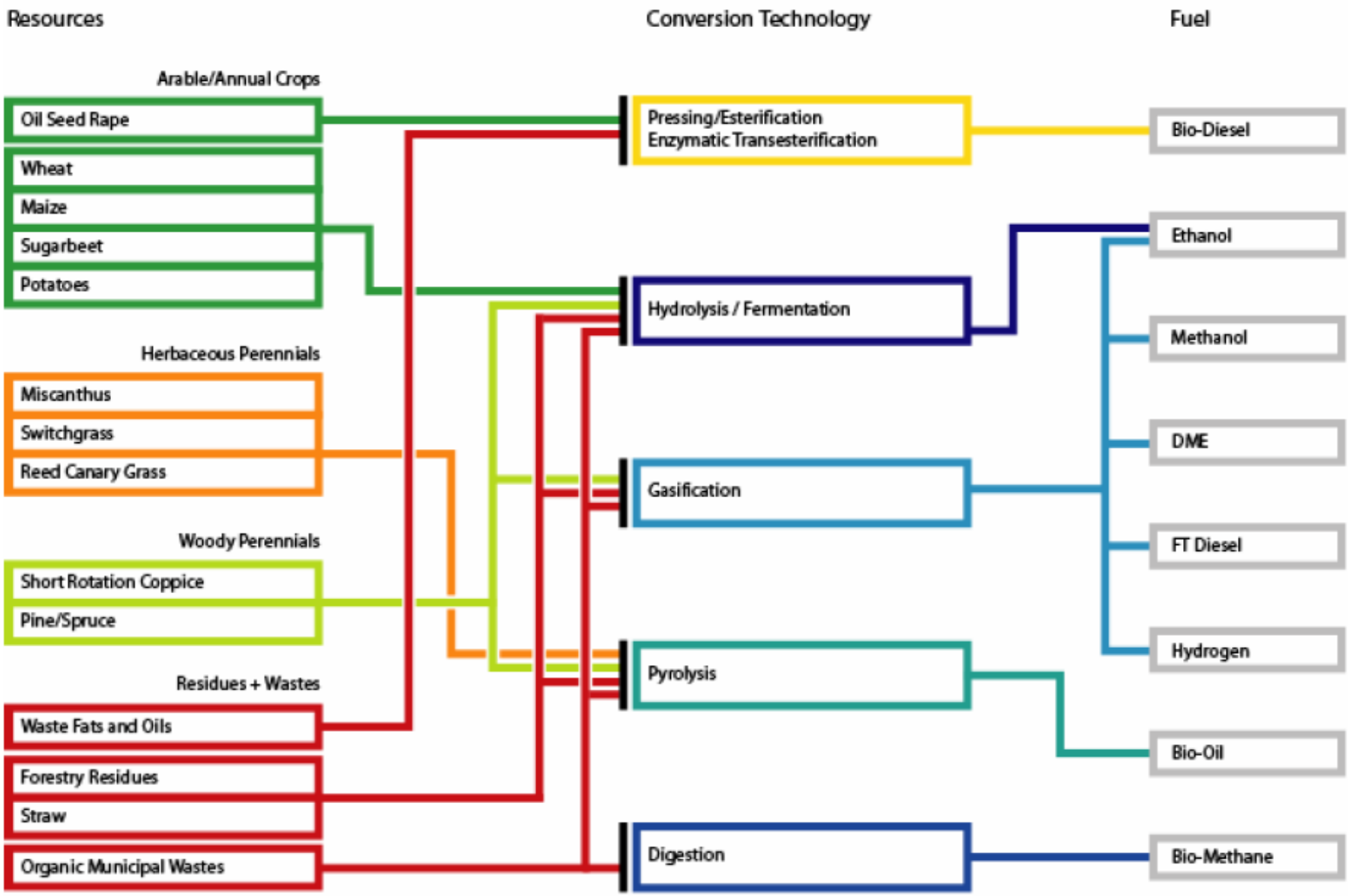
40 – 50 mpg CAFE

35 to 45 B Gals of Cellulosic Ethanol With Enzyme Break-thrus

Current Ethanol Production Methods



Possible Advanced Biofuel Pathways



Cellulosic Ethanol GHG Benefits

- The energy balance can approach 10 to 1.
  - i.e., for every unit of fossil energy, you get 10 units of energy out
- The return ratio > corn ethanol
- GHG reduction:
  - 18-20 % for corn ethanol
  - 85 % for cellulosic ethanol

Key Strategic Questions + Uncertainties

- What is maximum deployment potential of various low carbon fuel options?
- What is the timeframe for high volume production?
- Role of E- 100, E-85, E-5.7, E-10 ?
- Steady state ≠ dynamic LCA
  - How do we validate and update a CA GREET model?
  - How do we account for environmental damage (e.g., soil erosion) in LCA?

Exciting Initiatives

- DuPont's corn stover R & D
  - With John Deere & Co. & Diversa Corp.
  - R&D with Broin
- Shell / Iogen pilot plant
- BP
  - UC Berkeley Energy Bioscience Institute
  - Butanol R & D with Dupont
- ADM
- Celunol
- Cilion

Industry Innovation is Flourishing

- Dyadic Intl. + Abengoa
  - Nebraska ag waste pilot plant
  - C1 fungal cells, GMO Risk Group 0
- Genencor
  - Rochester biomass pilot plant with Mascoma
- Novozymes
  - $2.4 B partnership with Chinese Resources Alcohol Corp
- Tamarack Energy + Mascoma
  - one step conversion

Feedstock R & D Needs

- Process adaptation to broader spectrum of cell wall architectures
- Higher plant yields and tolerance
- Wider array of energy crop genome sequences
- Improved understanding of cell wall genetic structure & principles
- Enhanced understanding of soil nutrient / microbe dynamics

Conversion Process R & D Needs

- Increased # of fermentable enzymes
- Enhanced cell wall pretreatment
- More insight on cellulases, ligninases + hemicellulases
- Better regulation of cellulosome activity
- Better enzyme action on insoluble substrates

  (fundamental limits)
- Enhanced fungal enzyme production
- More insight on inhibitor processes

Sugar Fermentation R & D Needs

- Enhanced microbial regulation
- Better manipulation of novel microbes
- Wider utilization of all sugar types
- More stress tolerant microorganisms
- New microbial mechanisms & control methods

Process R & D Needs

- Enhanced microbial cellulose utilization
- Enhanced control methods
- Better process tolerance

Projects of Interest to AQMD

- Ethanol vehicle emissions characterization
- Phase 2 vapor recovery demonstration
- Increased E-85 fueling network utilization
- Vehicle Optimization / P-ZEV certification
- Life Cycle studies
- High volume pilot plant assessment
- Gasification technology optimization
- Feedstock readiness / economic assessments
- Other development / deployment concepts?

Conclusion

- Cellulosic ethanol potential is significant
- Integrates well with plug-in hybrids
- AQ benefits – especially toxics
- R & D needs are challenging
- AQMD looking to broaden our role
- Thank you for your participation in this meeting…