

*SHALE GAS WILL DRIVE
INNOVATION IN TRANSPORT FLUIDS*

2011 Sustainability Conference

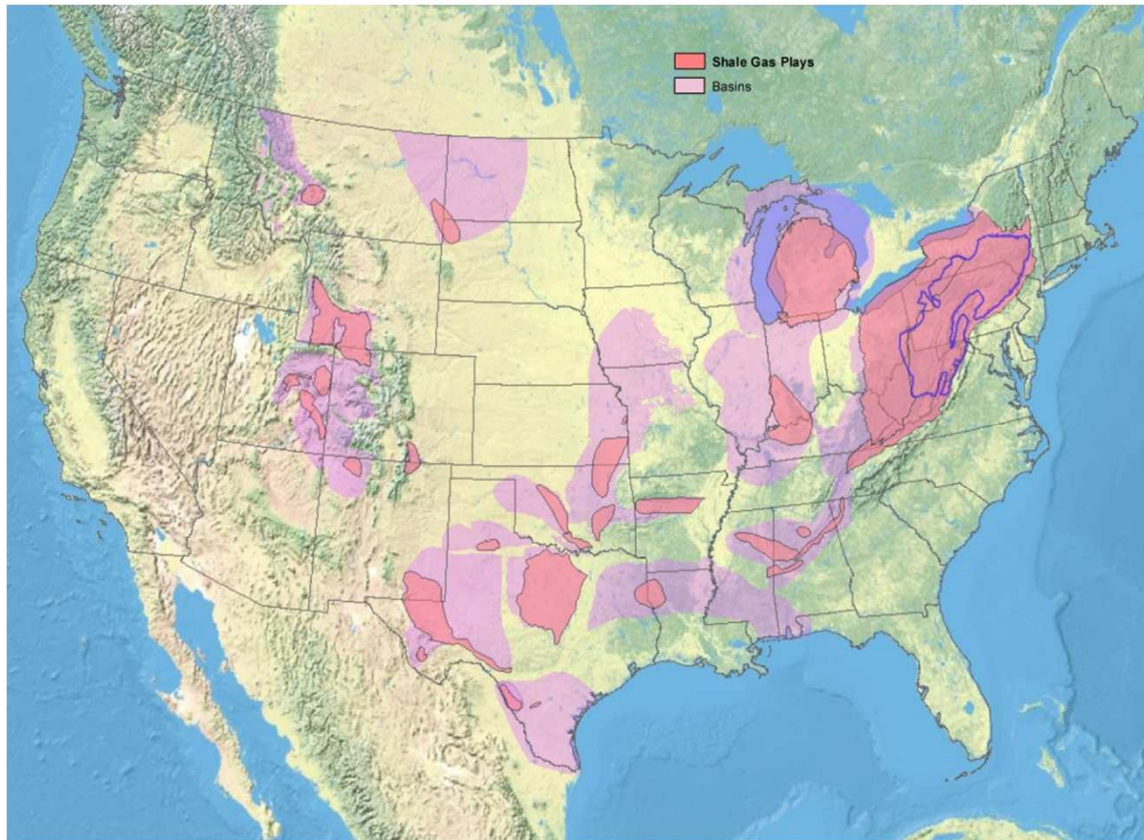
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Shale Gas in the US

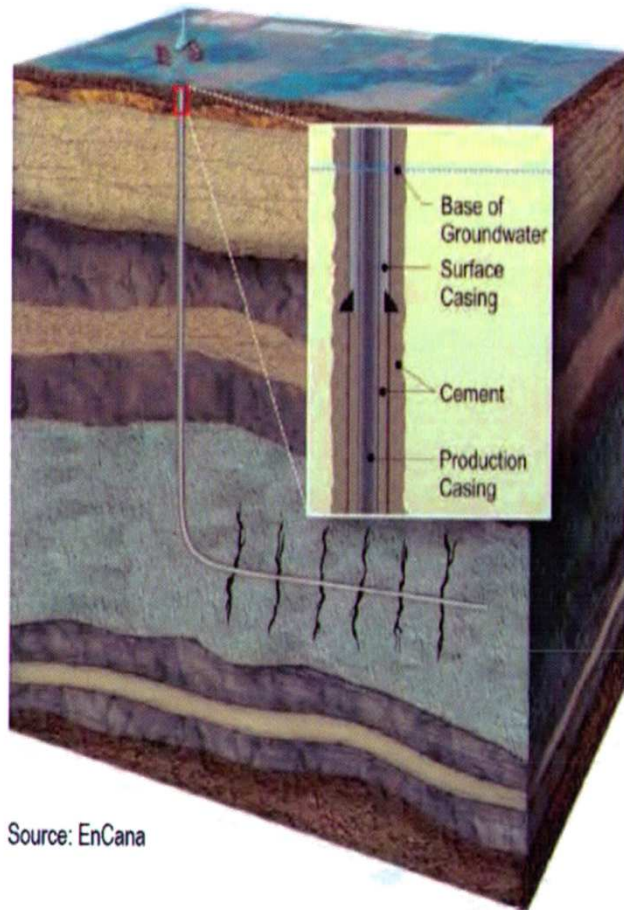


The Marcellus is close to major east coast demand

Photo Source: U.S. Energy Information Administration

What Changed the Game?

Horizontal Well with Multi-Stage Fracturing



Source: EnCana

- “Source Rock” was not considered for production unless naturally fractured
- Recognition that multi-stage **hydraulic fracturing** could create a “permeable reservoir” changed the game
- **Horizontal drilling** provided more drainage volume per foot drilled: reduced cost

Photo source: SPE Shale Course, George E. King and Ian Palmer

Shale Gas Environmental Concerns

Concern	Solution
Contamination of aquifers	Sound drilling practice Regulatory oversight
Fresh water withdrawals	Recycle frac water Use saline water
Flow back water disposal	Recycle frac water Deep Disposal Wells
Chemicals in fracture fluid	Greener chemicals

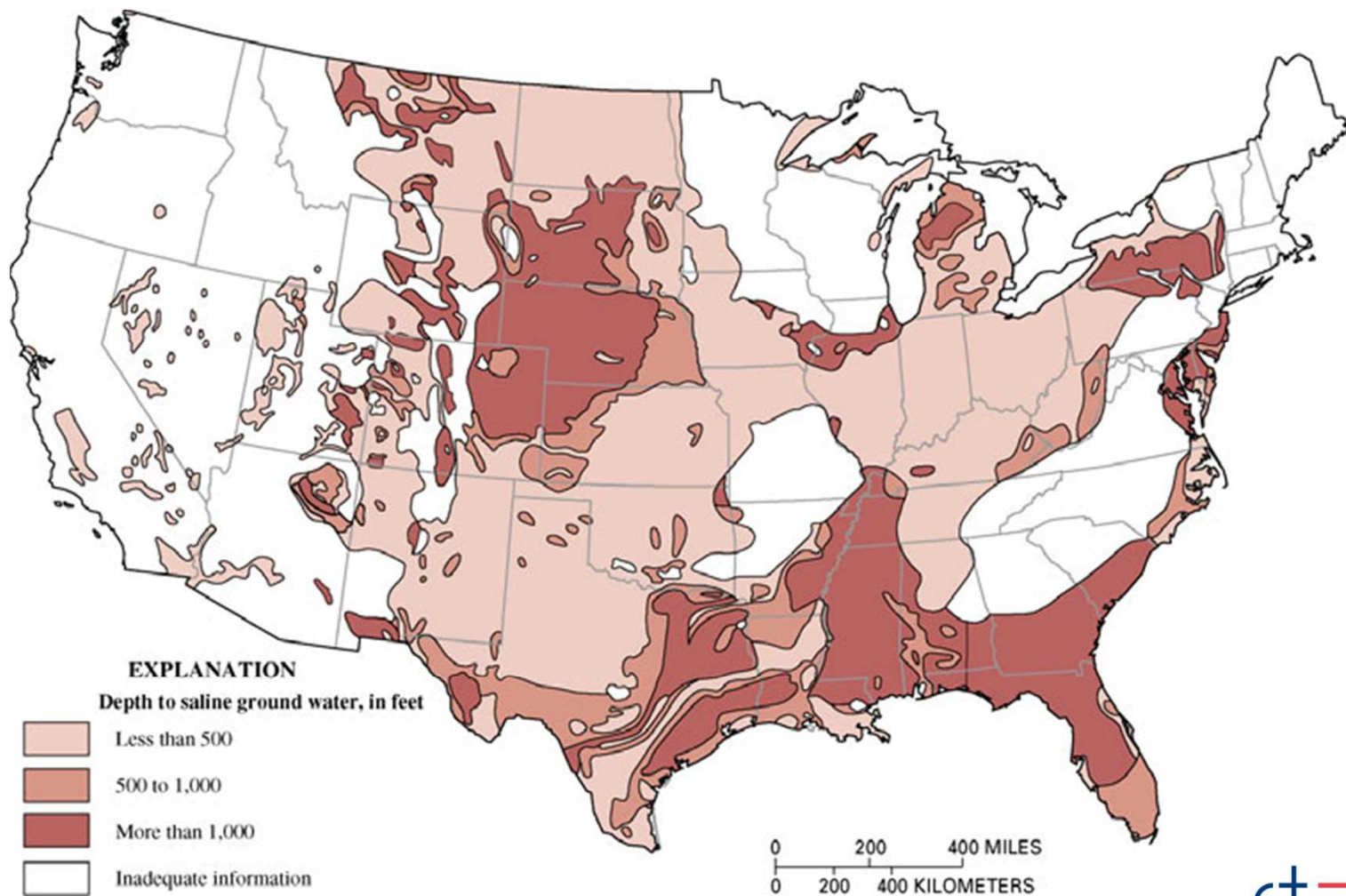
GOAL OF ZERO DISCHARGE AND ZERO WITHDRAWALS

REQUIRES

- Salt Tolerance
 - Allows easier re-use of flowback water
 - Allows use of saline waters of convenience
- Addressing Potential Issues with High Salt
 - Scaling: can be repository for radioactive species
 - Divalent ions can retard efficacy of cross-linkers, friction reducers
 - Reservoir effects need better definition
 - More desalination may be needed than with fresh water make up

SALINE WATERS OF CONVENIENCE

- **Sea Water**
 - Simplest to process
 - TDS average of 35000 ppm is already acceptable
- **Saline Aquifers**
 - Target shallow ones preferably for easy access and lower salinity
 - USGS has not mapped since middle of last century (see map)
 - Available maps show presence in many shale gas areas
 - Withdrawal could affect hydrology of proximal fresh bodies
- **Produced Water**
 - Potentially the most challenging
 - But use offsets need to dispose of



Shale Gas Environmental Solutions

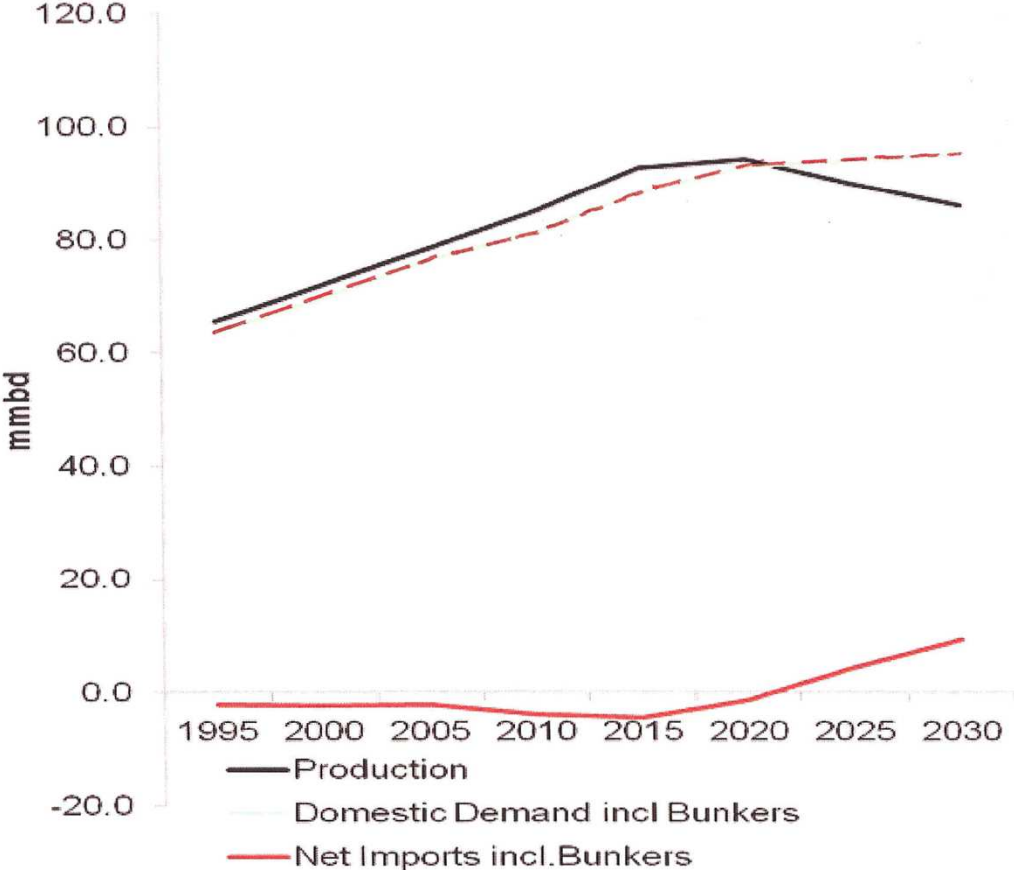
- Multiple wells from single pad reduces environmental footprint, improves operational and regulatory oversight
- Zero discharge target is achievable with water handling and processing technologies
 - Explore deep disposal: low cost when feasible
- Greening of fracture fluid chemicals is a tractable near term goal
- **Needed:** Industry innovation and transparency combined with community willingness to listen and cooperate

The Energy Transition—About 10 Years Away

Demand Must Fall—Unless Alternatives Can Fill the Gap



World Oil Balance

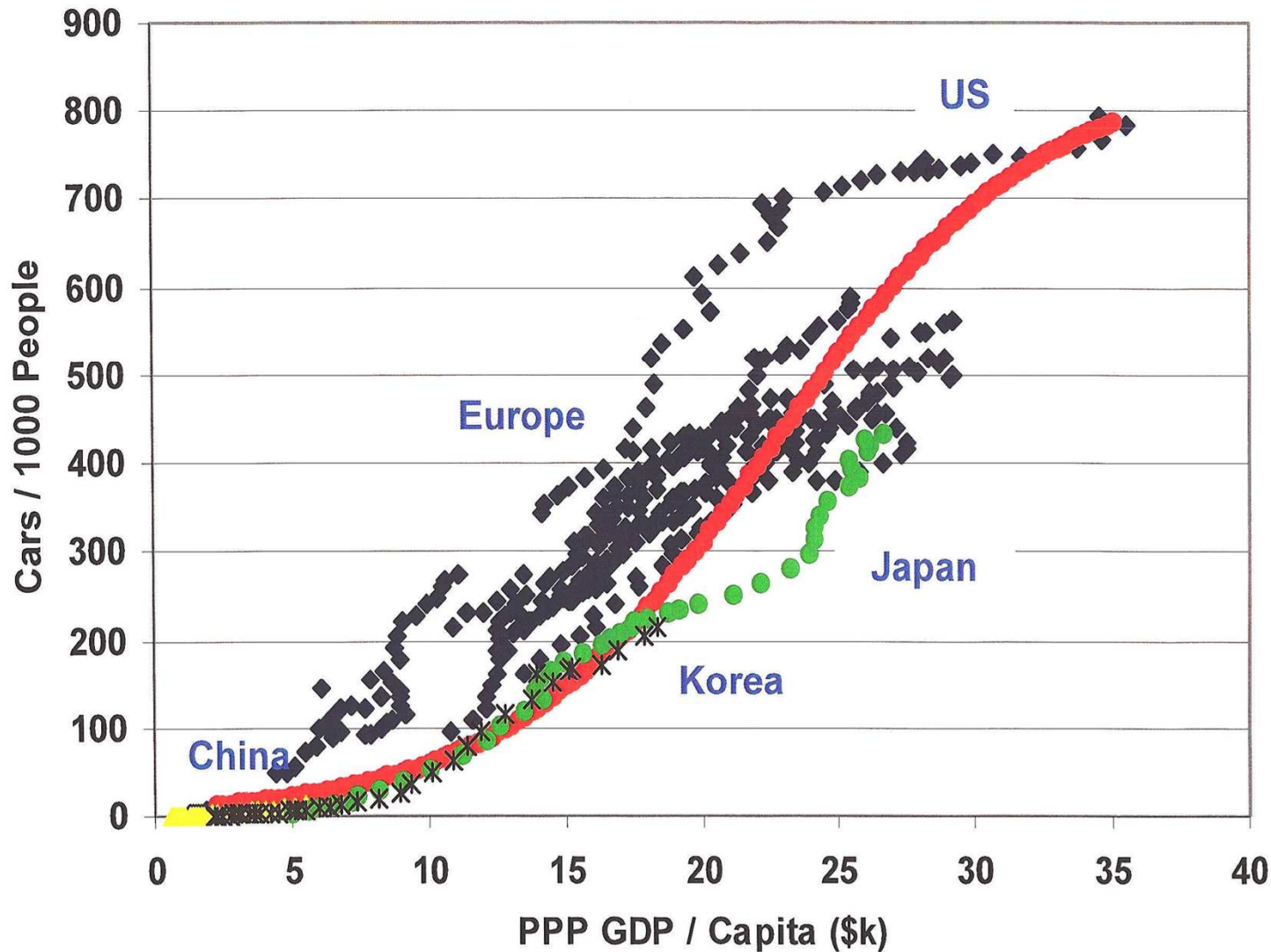


Private Vehicles—the Heart of the Problem

Growth in Non-OECD Car Fleet Just Beginning



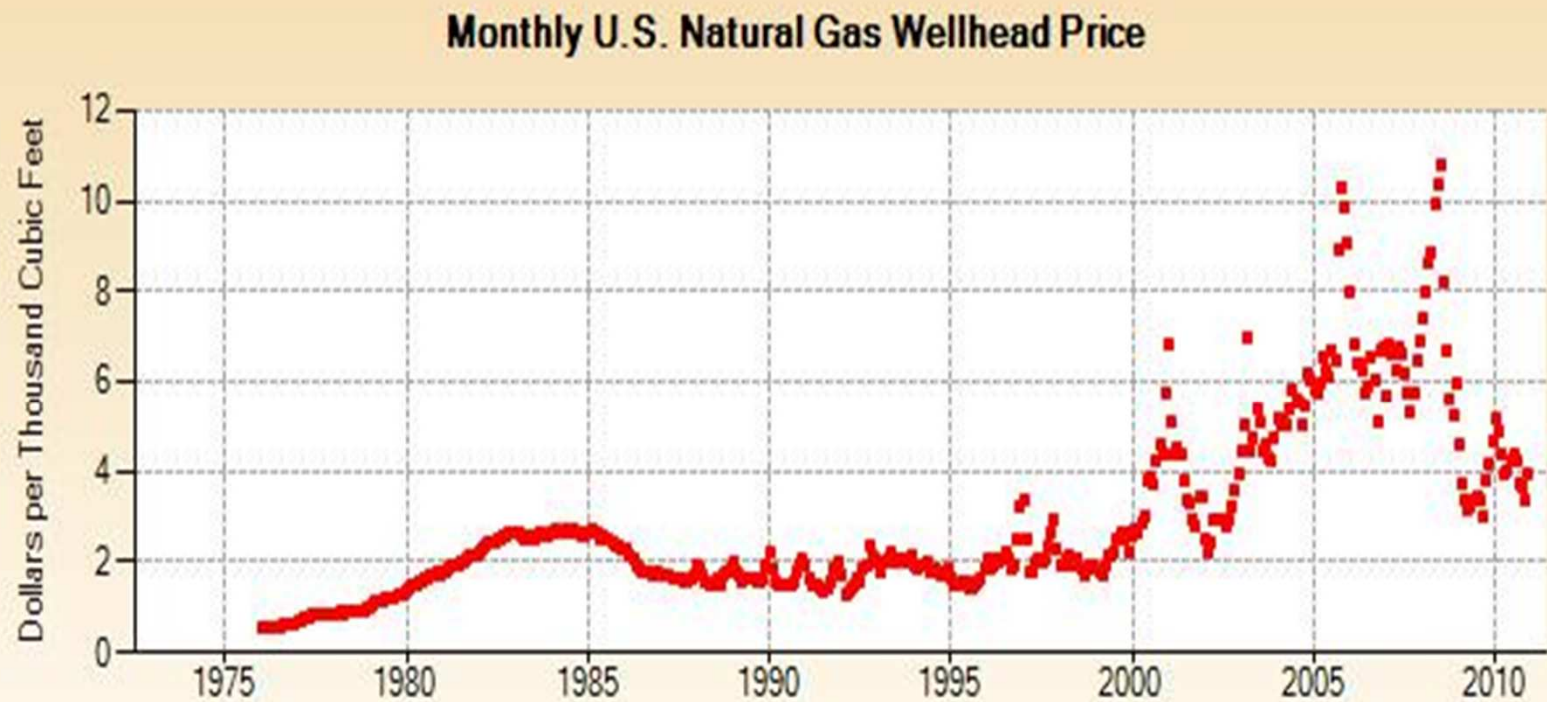
Cars per 1000 People Historical Data through 2003/04



REPLACING OIL WITH GAS

- *Gas, oil prices historically volatile*
 - *Gas: \$2-12 per MMBTU (see graph)*
 - *Oil: \$40-140 per barrel*
 - *Uncertainty hurts switches to gas*
- *Shale gas changed the game*
 - *Cost expected to be moderate and stable*
 - *Demand drives floor, fast new capacity assures ceiling*
- *Oil/gas price ratio today about 4*
 - *Expect to remain high*
 - *Will drive gas derived transport fuel solutions*

Natural Gas Pricing History



Source: U.S. Energy Information Administration

REPLACING OIL WITH GAS (contd.)

- *CNG for transport fuel*
 - *4x volume of diesel tank*
 - *public transport*
- *LNG for long haul, trains*
 - *1.4x volume of diesel*
 - *Infrastructure needed*
- *Gas to liquids*
 - *Technology needed to improve economics*
 - *Gasoline the preferred target*

North Carolina Implications

- *Investigate shale gas potential*
 - *Labor intensive*
- *Modify laws to allow: horizontal drilling, fracturing*
- *Address environmental issues from outset*
 - *Saline water resource estimation*
 - *Deep disposal feasibility study*
 - *Set zero discharge targets and timeline*
 - *Regulatory oversight on well quality*
 - *Pad drilling for all but early stage development*

North Carolina Implications (contd.)

- *Investigate gas to liquids*
- *Companion with biomass to liquids*
 - *Technology identical after syngas production step*
- *Modify state fuel import reduction targets*
 - *Allow NG for transport as valid contribution*
 - *Only for domestic natural gas?*