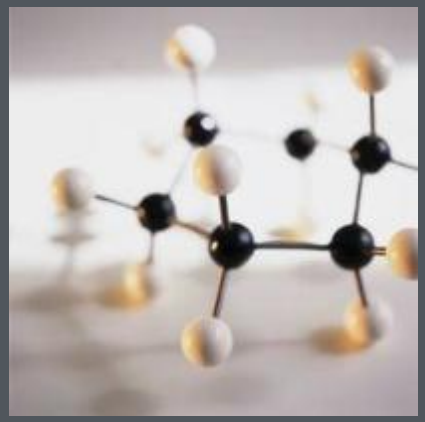
A Review of Alternative Biofuel Technologies



4th International Conference on Biofuels Standards

NIST – Gaithersburg, MD

November 14, 2012

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Independent Consultant

Outline

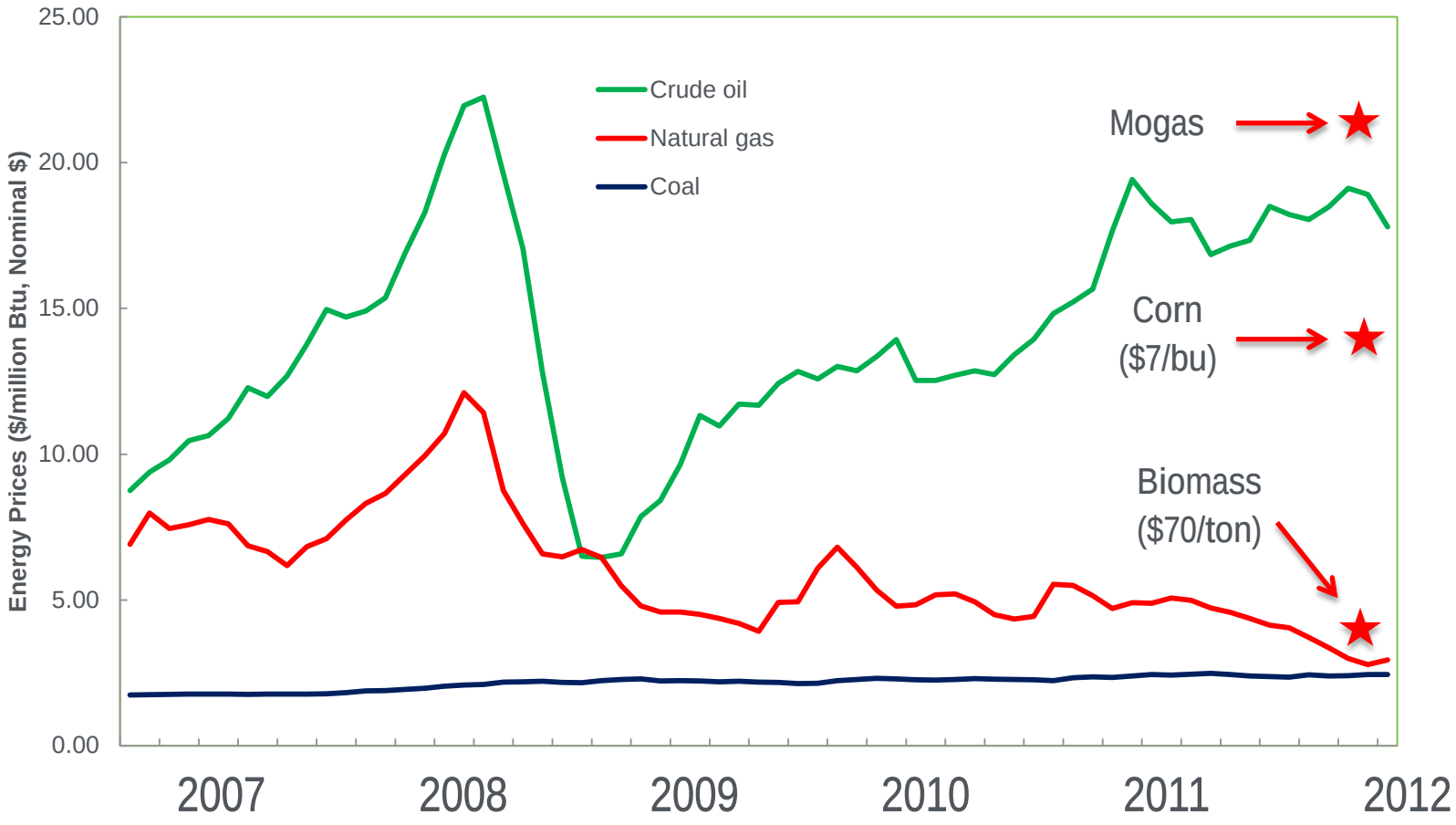
- An Admission
  - I am a Recovering Thermodynamicist
    - API Data Book, Expt'l Thesis – Penn State (Daubert & Danner)
    - Doctoral Work – UC-Berkeley (Prausnitz)
    - Post-Doc – Ecole des Mines, Paris (Renon)
  - 19 Years Thermo Free!!!

- Today's Talk:
  - Current Environment (Technology, Policy, Economics)
  - Advanced Biofuels Technologies (Types, Progress, +/–)
  - The Path Forward

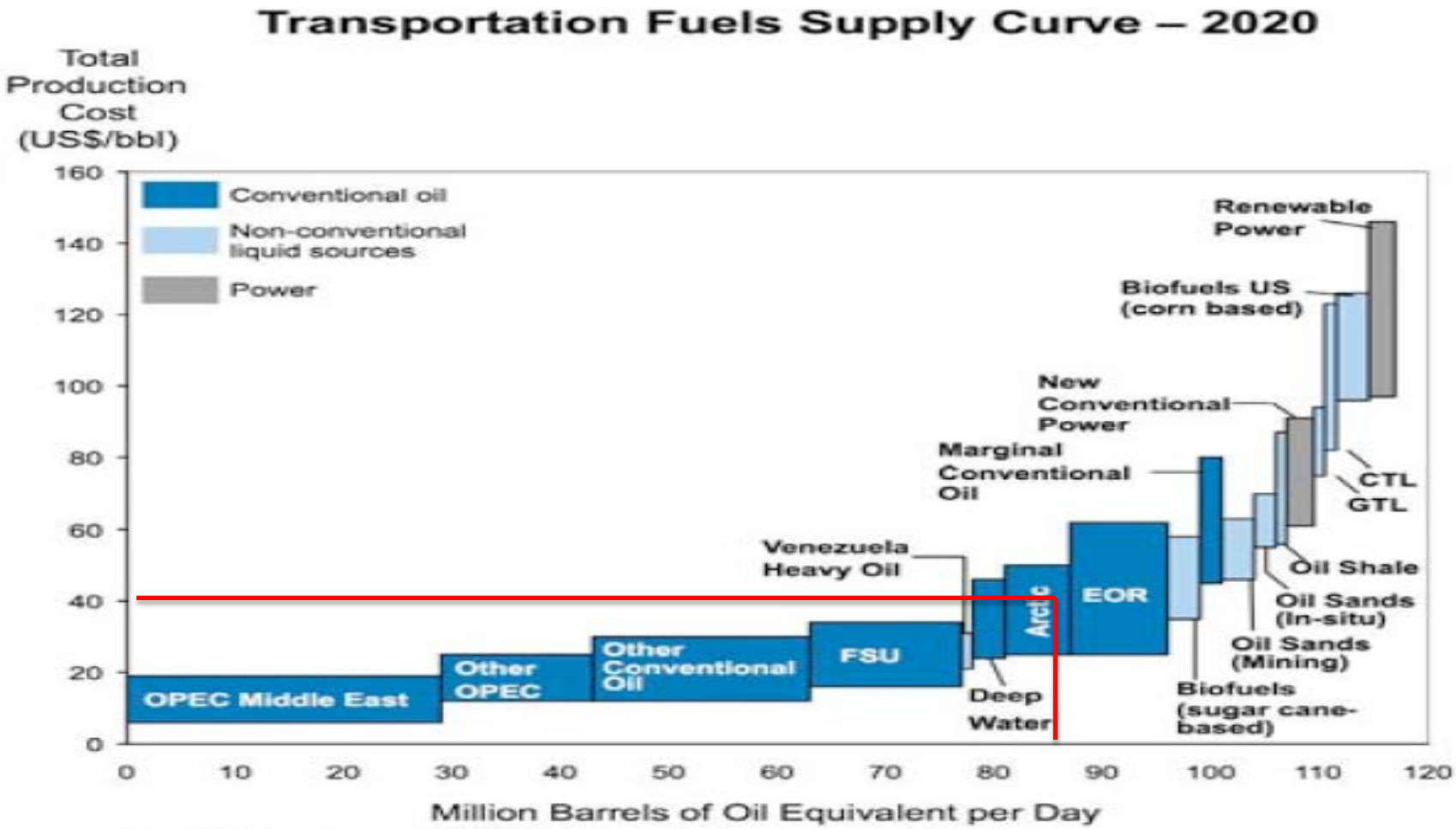
Outline

Energy Consumption (2009)	Quads / year	% of Total
Petroleum	150	37
Coal	88	22
Natural Gas	85	21
Nuclear	25	6
Biomass	4	1
All Other Renewables	30	7

Energy Prices (with thanks to Zia Haq!)

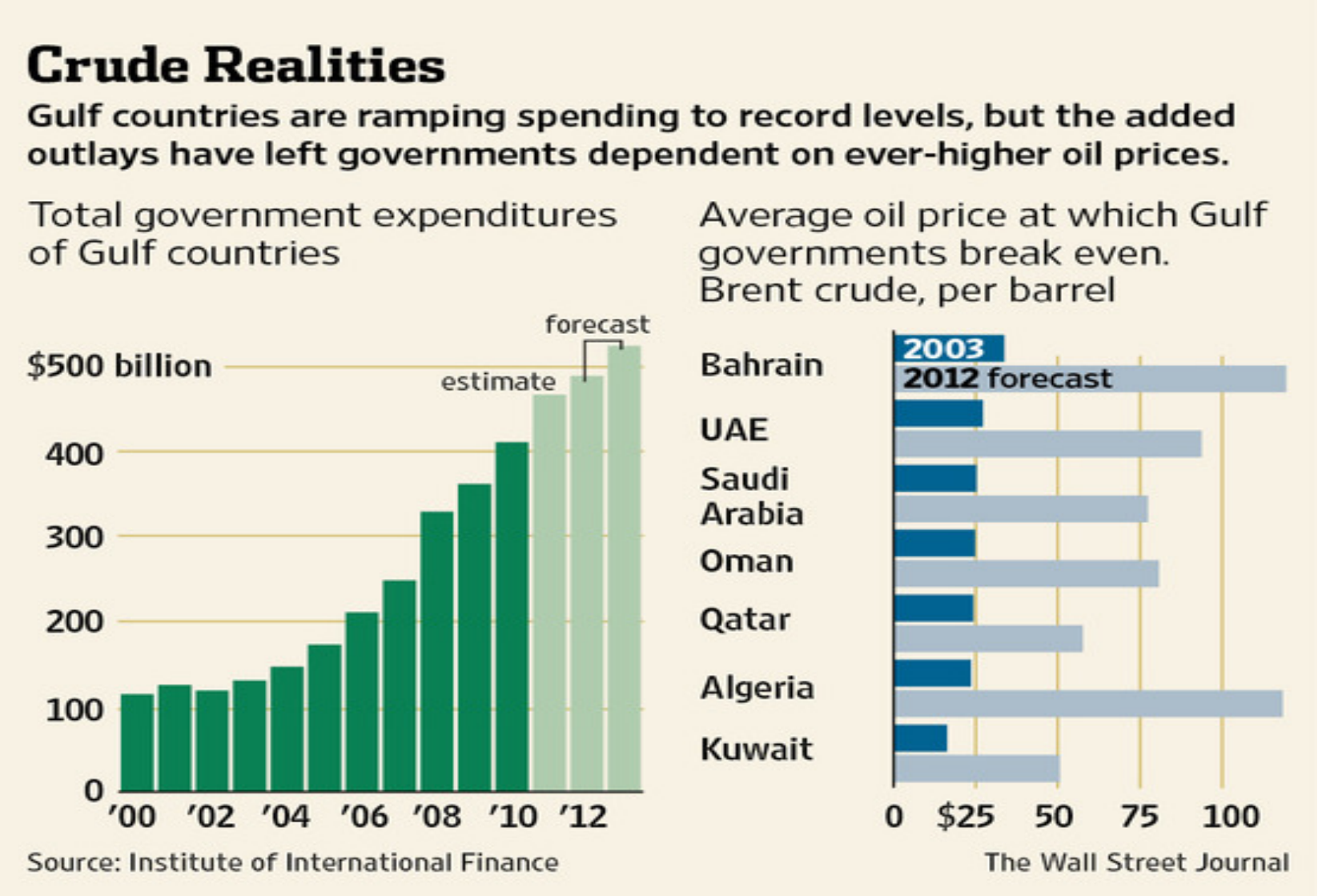


Crude Oil Cost-Price Conundrum



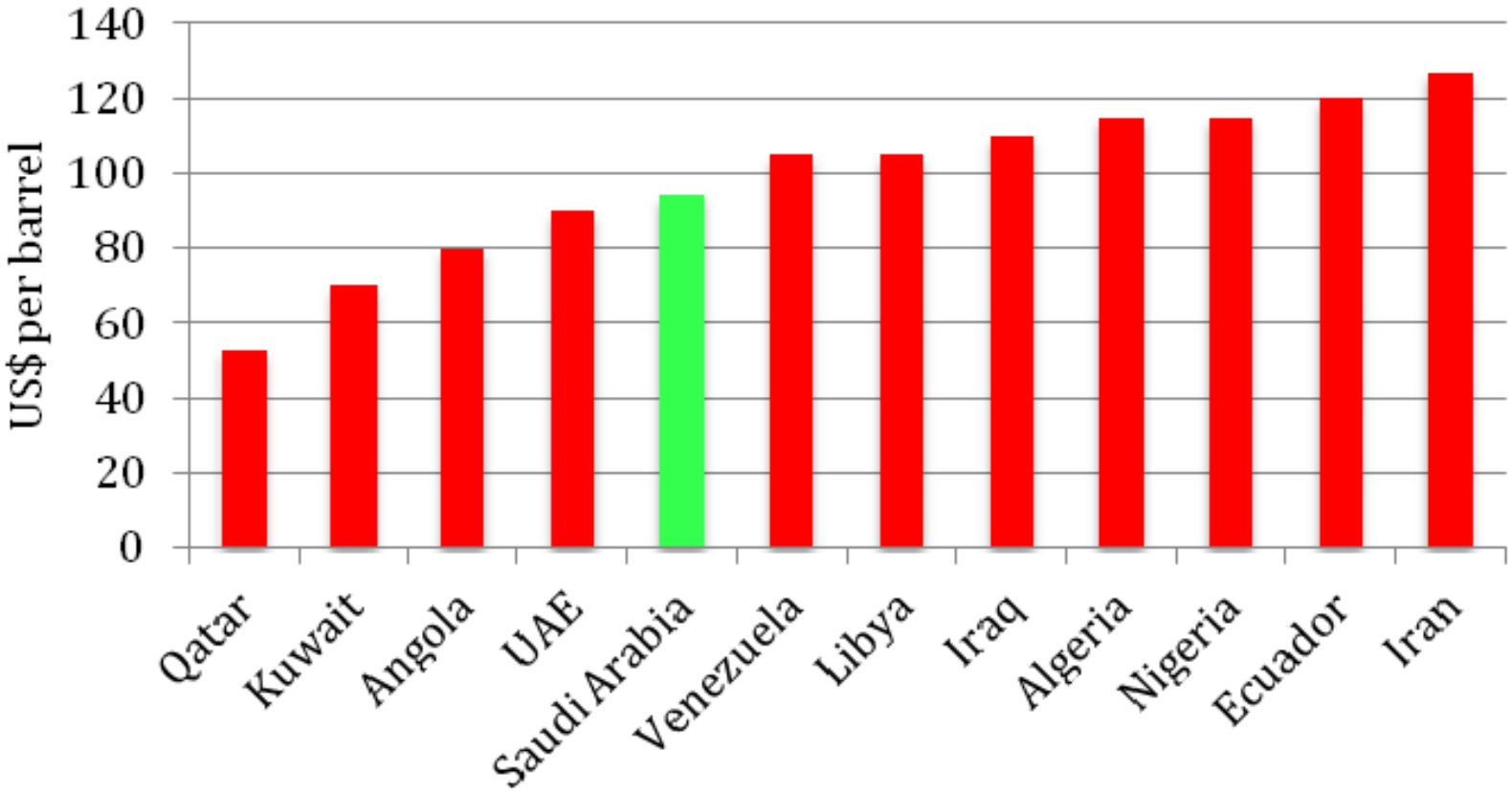
Note: EOR – Enhanced Oil Recovery
Source: Booz & Company analysis

“Oil Addiction” is Catching



“Oil Addiction” is Catching

OPEC median budgetary breakeven price



Source: Ali Aissaoui, *Apicorp Economic Commentary,* Vol. 7, No. 8–9, August–September 2012.

Fossil Fuels are not “Carbon Copies”

- At Today’s Prices:
  - COAL: $ 60 / Ton Carbon ($ 3.50/Btu)
  - GAS: $210 / Ton Carbon ($ 3.50/Btu)
  - CRUDE OIL: $310 / Ton Carbon ($17.80/Btu)

- Carbon taxes would have to be high enough to wipe out coal before they’d have a meaningful effect on crude oil.

- Additional Price Pressures:
  - Coal, NGL’s (C_2, C_3) & Biomass for Chemicals
  - “Demand Destruction” from Higher m.p.g., PHEV’s, EV’s, etc.

“Alternative” Biofuels - 1

- Biological
  - Cellulosic Sugar (Renmatix, EdenIQ, Virdia, Sweetwater, DuPont, Novozymes, Mascoma, Chemtex/Proesa, BP/Verenium, et al.)
  - Sugar to Butanol (Gevo, Butamax, et al.)
  - Sugar to Lipids (Solazyme, LS9, et al.)
  - Sugar to Hydrocarbons (Amyris, DuPont/Genencor, Global Bioenergies, et al.)
  - Hybrid: Syngas-to-Ethanol (LanzaTech, INEOS, Coskata)

- Photo(bio)chemical
  - Photbiocatalytic (Joule, et al.)
  - Sunlight-to-fuels, artificial photsynthesis, etc.

“Alternative” Biofuels - 2

- Thermochemical
  - Gasification / Fischer-Tropsch (Rentech, et al.)
  - Pyrolysis (Ensyn/UOP (Envergent), KiOR, et al.)
  - Liquefaction (Virent, Anellotech, Cool Planet, et al.)

- Oleochemical
  - Phototrophic Algae (Sapphire, Celana, et al.)
  - Novel Oilseed Crops (SG Biofuels – Jatropha, Sustainable Oils – Camelina, et al.)
  - Renewable Hydrotreated Diesel & Jet (Neste, CLG, et al.)

Which (if any) will be the Winners?

- Guiding Principles
  - Minimize new capital, especially in the field at small scale
    ($8/gal-yr (ambitious) is 4x the cost of a greenfield refinery)
  - Maximize biomass yield to fuel (or higher) value products
    (get >Btu value for lignin to compete at fuel prices)
    (lignin = 25-50% of total energy; costly to “burn”)
  - Maximize process flexibility to drive the “Supply Wheel”
    (Minimize storage & transportation costs, minimize upsets)
  - Don’t move water or bulk biomass very far
    (liquids or densified quasi-fluids for long-distance haul)
  - Avoid slow / dilute conversion processes
    (“cooking,” biological processes, solids handling = large equip’t)

And so?

- As practiced today, under current policies, biological processes and gasification will not compete at fuel prices
- Pyrolysis and liquefaction technologies have a chance, if they can fully utilize lignin, keep field capital costs low, and maximize use of existing refinery capacity
- Biological processes will compete for value-added chemicals, where conversion specificity is advantageous
- Biological processes may compete for fuels if cellulose hydrolysis and FS logistics can be *greatly* improved
- Gasification may compete for fuels when it can be cited close to an electricity consumer, or if methanol can be developed into a flexible intermediate

However . . .

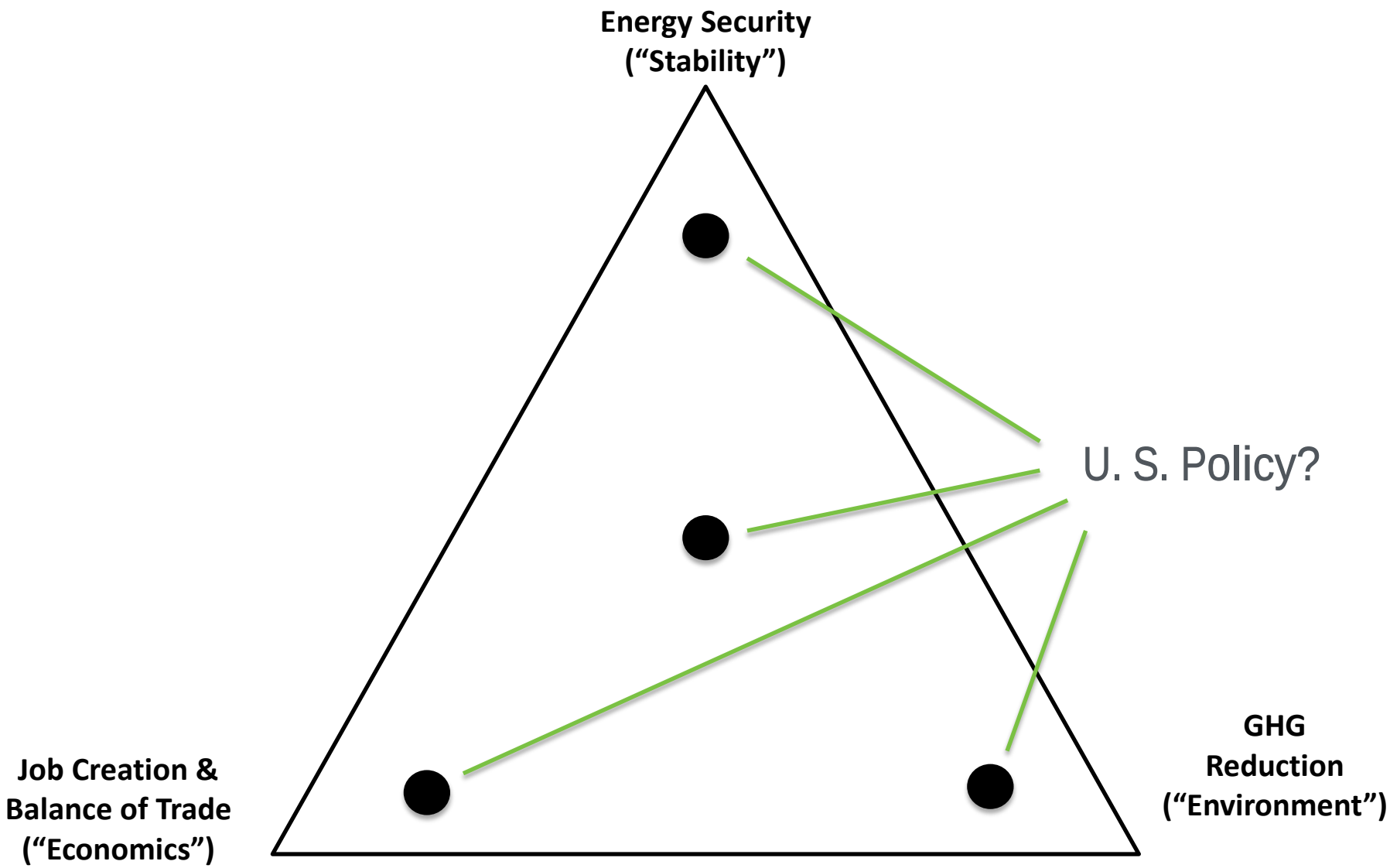
- NOTHING will be viable in competition with crude oil unless policies level the playing field
  - Pump prices only reflect extraction, refining, transportation, etc.
  - Consumers bear massive societal and environmental costs, but these are “hidden” in military and other spending.
  - Consumers (and biofuels investors) have no monetary means to reap the true benefits of biofuels.

- Also, many if not most of the companies discussed above have shifted AWAY from fuels toward chemicals, one large cellulosic ethanol project has been canceled, and at least one other may be “on hold”

It’s the Stoichiometry, Stupid!

Material	Carbon	Hydrogen	Oxygen
Coal	1	<1	<<1
Methane	1	4	0
Crude Oil	1	~2	<<1
Biomass	1	<2	<1
Sugar	1	2	1
Fuels	**1**	**~2**	**0**
Chemical	**1**	**1 - 2**	**0 - 2**

Policy – No Coherent Priorities in USA



Thank You!