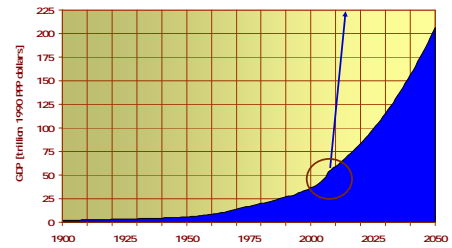




## An Energy Thesis of Economic Growth

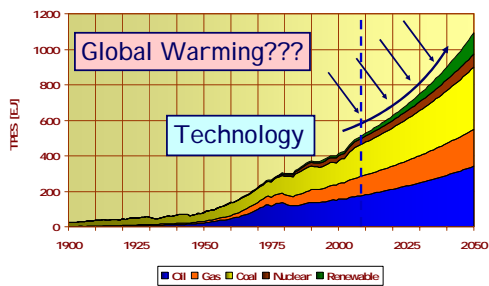
Willem Nel and Gerhardus van Zyl  
September 2009

## The "Official" Future



Slide 2

## The "Official" Future



Slide 3

## Too good to be true?

- Demand driven models - supply?
- Energy security.
  - Physical realities.
  - Non-renewable.
  - Laws of physics.
- Energy is an essential input to all regenerative physical processes!
- What is available?
- What can be accomplished?

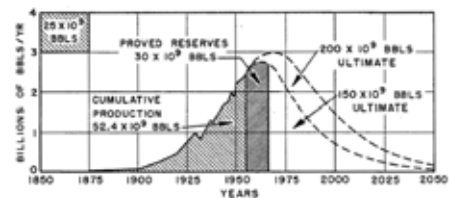
Slide 4

## Presentation

- Energy Resource Assessment.
- Economic Growth.

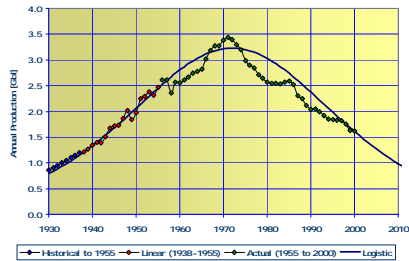
Slide 5

## M King Hubbert (1956)



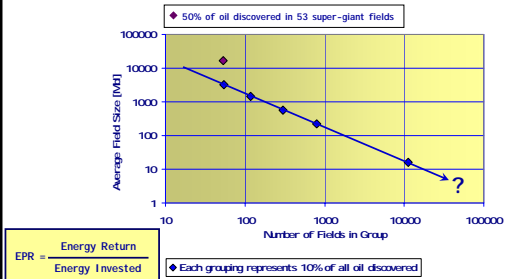
Slide 6

## US L48 Production



Slide 7

## What Logistics?



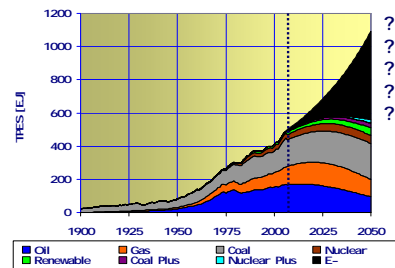
Slide 8

## Energy Reference Case (ERC)

- Logistics analysis
  - Oil, gas, coal
- Institutional views
  - Renewable
- Systemic interpretation of institutional knowledge and technical factors
  - Nuclear

Slide 9

## "Plausible" Energy Future



Slide 10

## Presentation

- Energy Resource Assessment.
- Economic Growth.

Slide 11

## Key Assumptions

- Economic output is explicitly derived from energy consumption (directly and indirectly).
- Energy intensity (energy consumed per unit of economic output) can be diminished by technology improvements within the constraints of the physical sciences.
- A globally aggregated model captures inter-sectoral and inter-state economic dependencies in the trade and utilization of energy commodities accurately.

Slide 12

## Economic Growth Model

$$Y = A_0 e^{at} \sum_i [\mu_{\text{eff},i}(t) E_{\text{Th},i} - \xi(t, E_i)]$$

Summation (i) = Oil, Gas, Coal, Nuclear, Renewable

Augmentation Function (Human Ingenuity)

Overall Effective Energy Efficiency

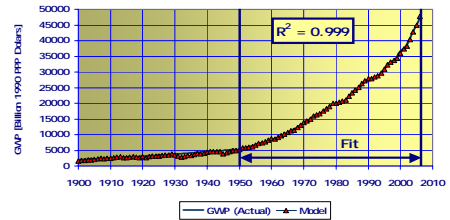
Energy Content (Thermal Heat Equivalent)

Energy Cost (EPR: Exploration, Extraction, Transport)

$$\mu_{\text{eff}} = \mu_0 + \frac{\mu_1}{1 + e^{-c(t-t_0)}}$$

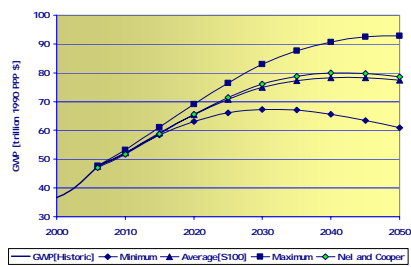
Slide 13

## Empirical Fit



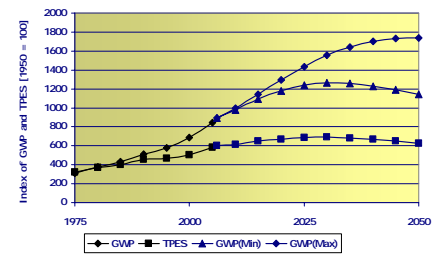
Slide 14

## Forecast: GDP



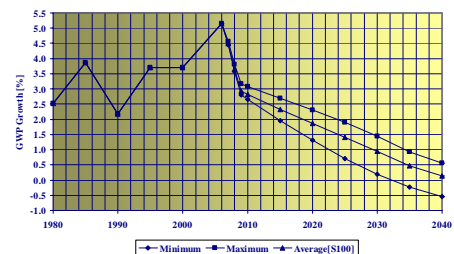
Slide 15

## Forecast: Decoupling



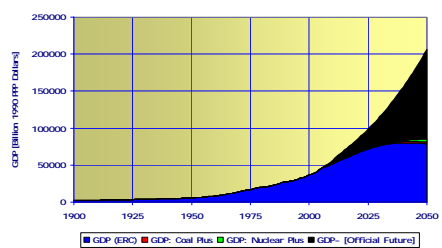
Slide 16

## Growth: Zero-Sum-Game?



Slide 17

## Plausible Future?



Slide 18

## Thank You

---

### Presentation References:

- Nel, W.P., 2009, Impacts of Primary Energy Constraints in the 21<sup>st</sup> Century, PhD Thesis, University of Johannesburg.
- Nel, W.P. and Cooper, C.J., Implications of fossil fuel constraints on economic growth and global warming, Energy Policy 37,1 (2009) 166–180.
- Nel, W.P and van Zyl, G, 2009, Defining Limits: Energy Constrained Economic Growth, Applied Energy, article in press, doi:10.1016/j.apenergy.2009.06.003