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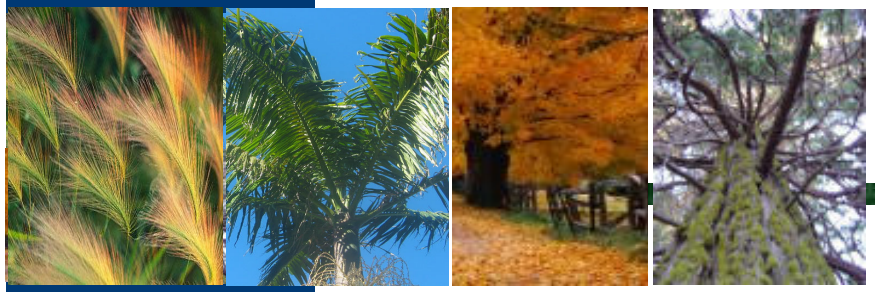

Geoenvironmental Risk, Green Asset Management, Sustainability, and Option Pricing Theory

R. David Espinoza
Columbia, MD

PGS
April, 2008

4/18/08

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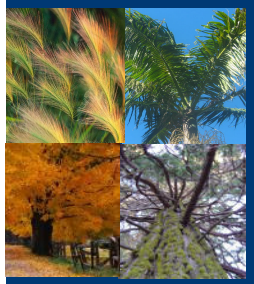
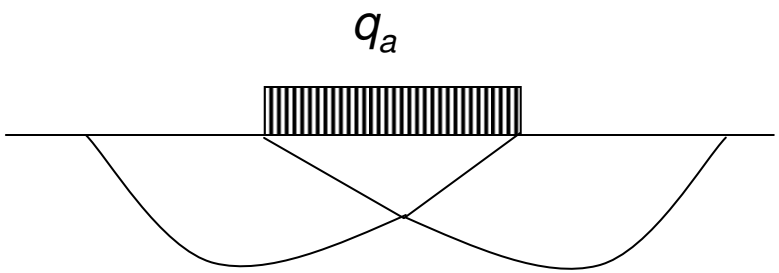


Geoenvironmental Risk

- **Geoenvironmental Engineering is not an exact science**



- **Model risk: $q_u = cN_c$**
- **Parameter Risk: c**
- **Loading Uncertainty: q_a**
- **Soil characterization**

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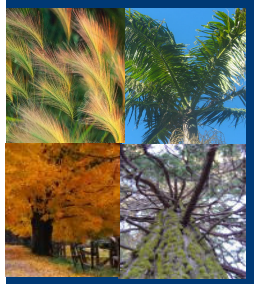
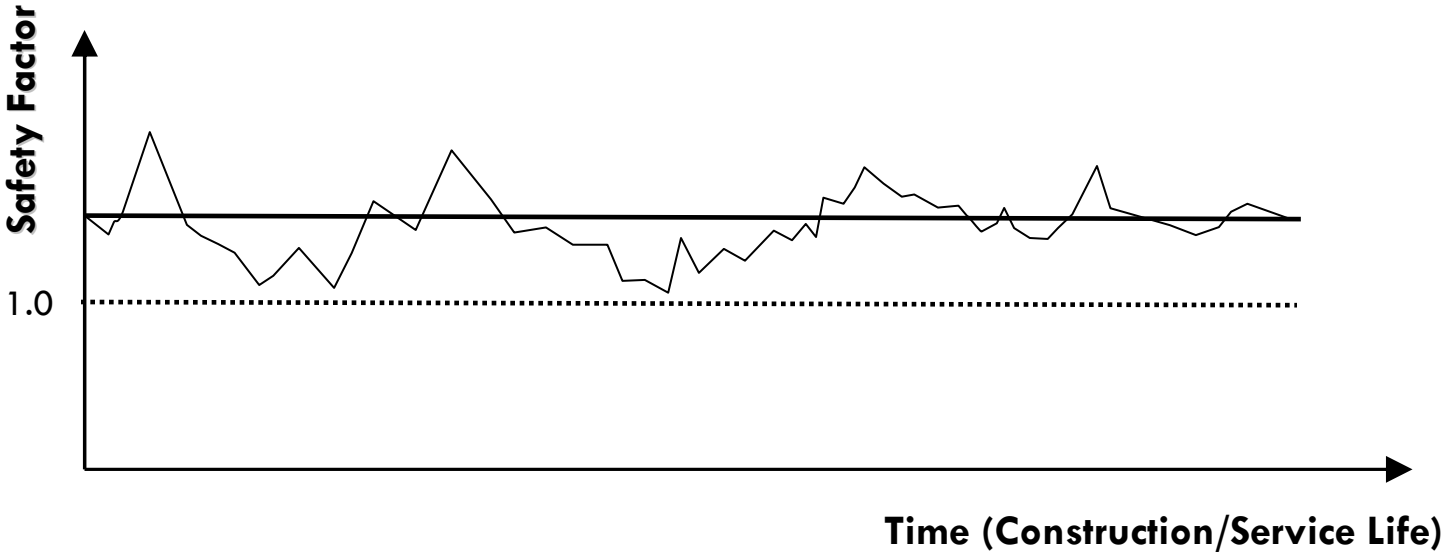


Geoenvironmental Risk

- **How to evaluate the technical risk?**
  - **Factor of safety?**
  - **Safety Margin?**
  - **Probability of failure?**



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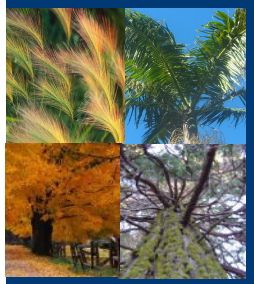

Geoenvironmental Risk

- Need to think in terms of financial risk (e.g., repair cost, project overbudget)
- The key is to convert technical risk to financial risk
- Then we can use financial risk tools
- One such tool: Option Pricing Theory

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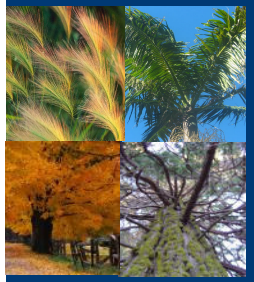

What is an option?

Options are financial instruments (e.g., puts, calls) whose values depend on other more basic underlying variables (e.g., stock).

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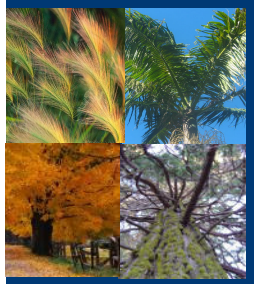

Options 101 – Call Option

- **Buyer has the right (but not the obligation) to buy a commodity or stock from the seller of the option at a certain time for a certain price (the strike price).**

- **Seller has the obligation to sell the underlying asset at the agreed strike price, if the buyer exercises the option.**

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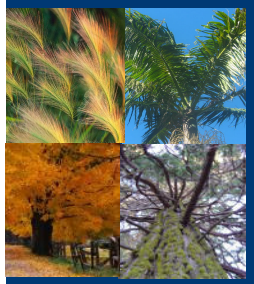
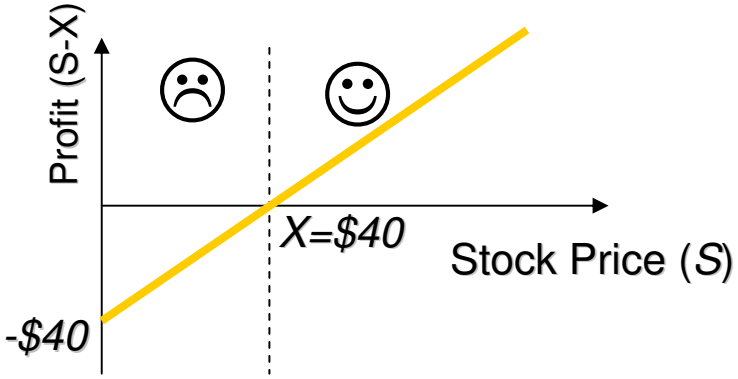
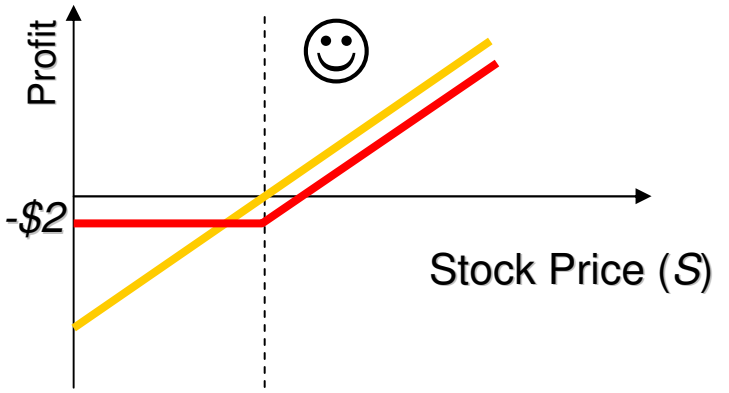


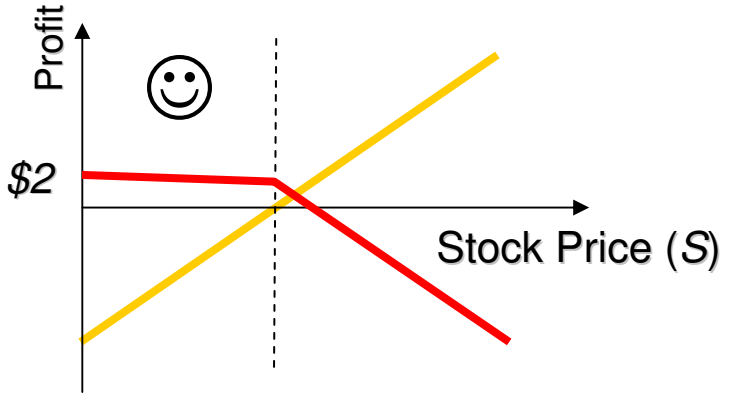
Financial Options 101



A. Buy stock (at price *X*)



B. Buy call option (at price c<<X)



C. Sell call option

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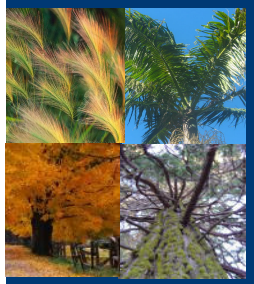
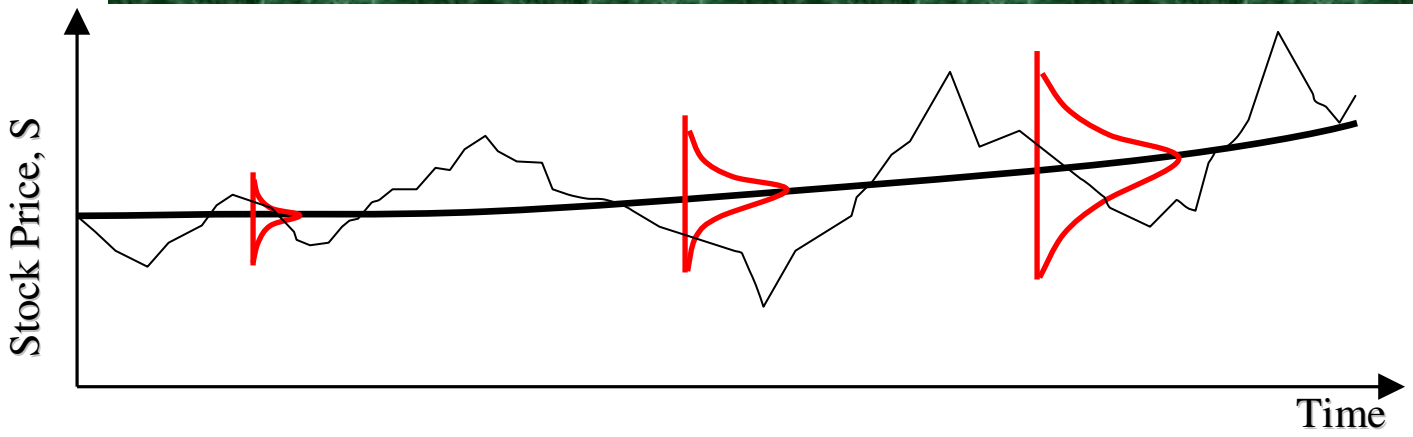


Random Movement of Stock Prices



Measure of Risk of stock price (S)

$$dS = \underbrace{\alpha S\,dt}_{\text{Deterministic}} + \underbrace{\sigma S\,dz}_{\text{Random}}$$

$\mathrm{E}[dz]=0$

$\mathrm{Var}[dz]=dt$

Call Price (Black and Scholes, 1973):

$$\frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} + (r-\delta) S \frac{\partial C}{\partial S} - rC + F_t = 0$$

B.C. $\quad t = T,\ C = Max(S - X, 0)$

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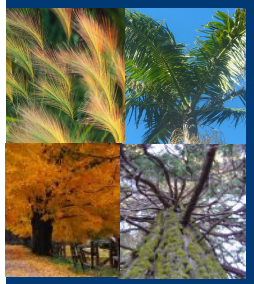
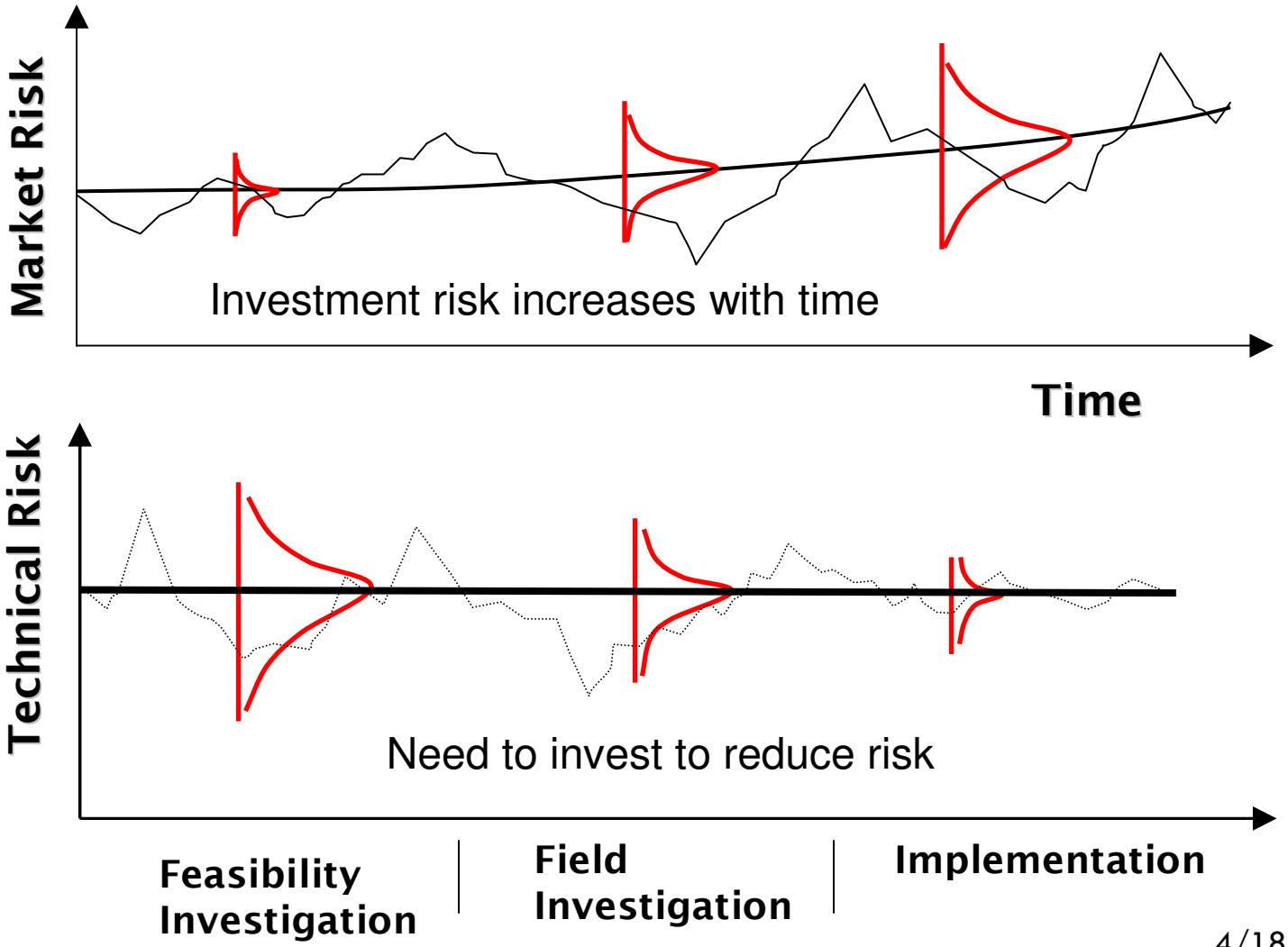


Comparison of Market and Technical Risk



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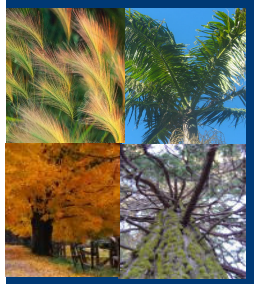
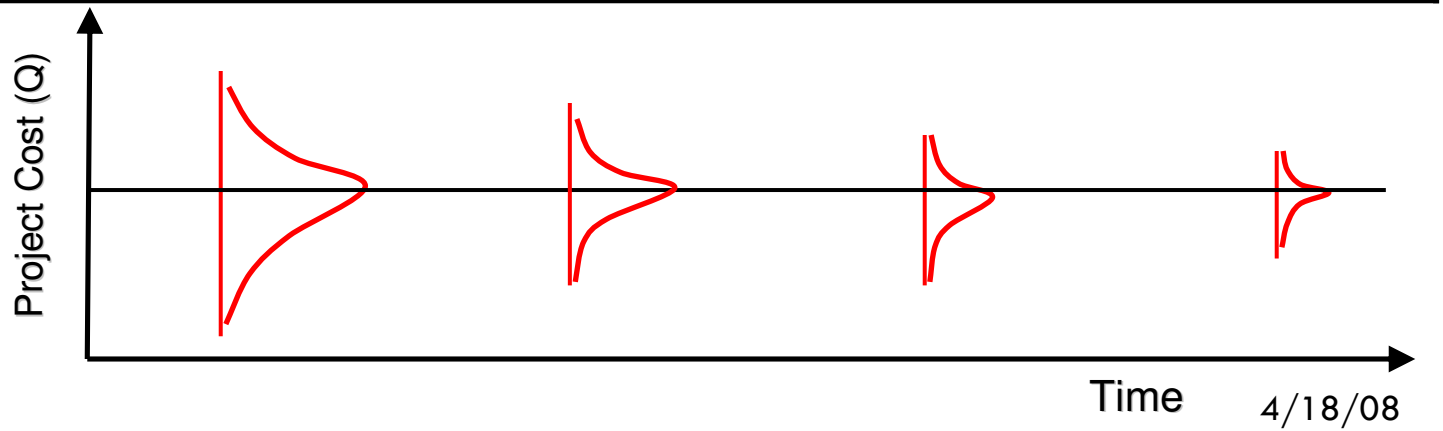


Evolution of Cost/Project Uncertainty

	Pre-Bid (Engineer's cost estimate)	During Bid (contractor's cost proposals)	Selected Bid (Low-bid price)	During Construction
Unit Price	Unknown	Known, Multiple	Known	Known
Quantity	Some Unknown	Some Unknown	Some Unknown	Known
Means & Methods	Unknown	Known, Multiple	Known	Known
Uncertainty	σ_1	σ_2	σ_3	σ_4



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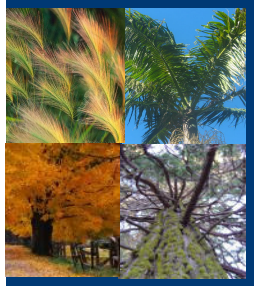

Geoenvironmental Risk

- **Main challenges:**
  - **Selection of the stochastic model**
  - **Inability to measure**
  - **No price discovery**
  - **Law of large numbers won't bail us out**

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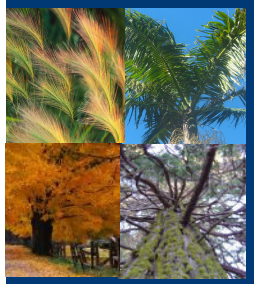
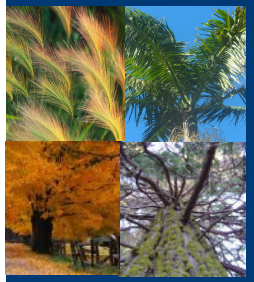
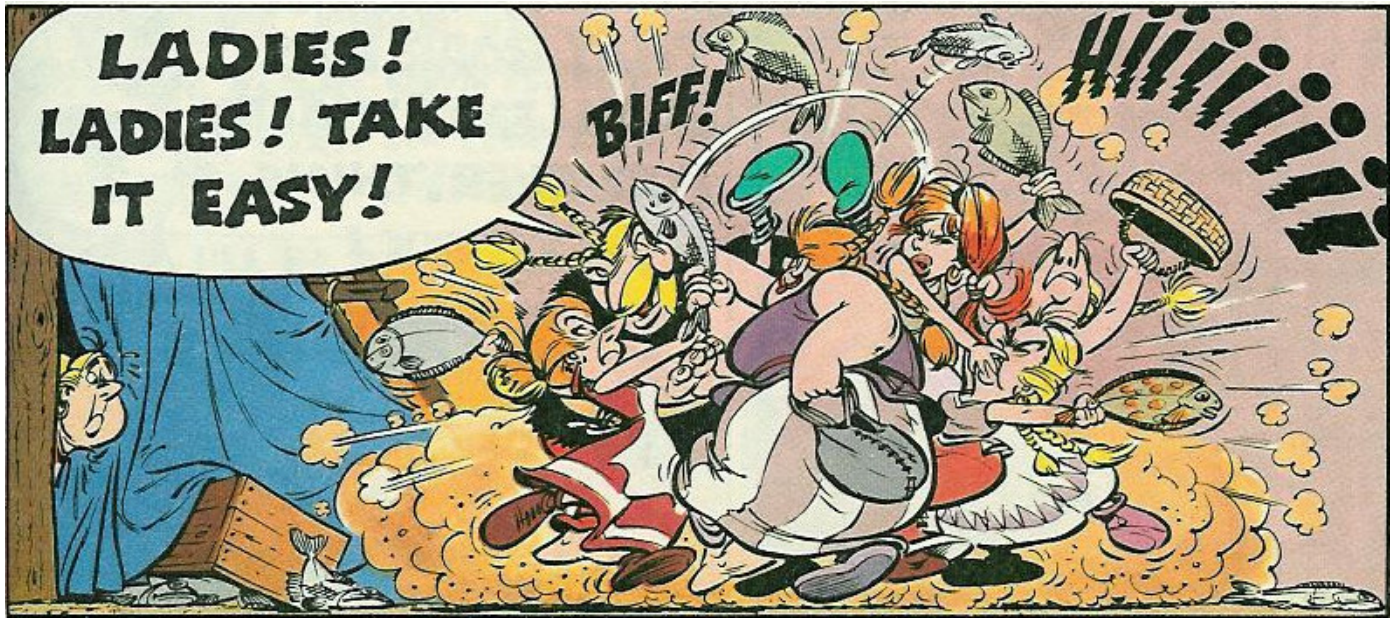


Geoenvironmental Risk

- **Main advantages:**
  - **Connects design with performance**
  - **Statistic/stochastic models are already applied in geo-environmental problems (e.g., LRFD)**
  - **Fosters innovation as risk could be shed/hedged/transferred**
  - **Integration with market risk**



What do all these have to do with the price of fish (i.e., sustainability)?



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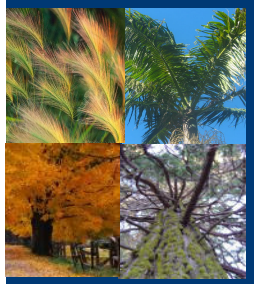

Sustainability

- **The 1987 Brundtland Definition [World Commission on Environment and Development (WCED)]: *"Humanity has the ability to make development sustainable – To ensure it meets the needs of the present without compromising the ability of future generations to meet their needs"***

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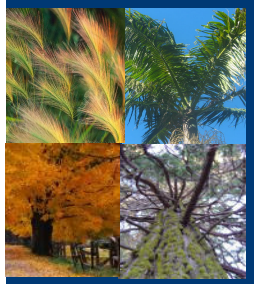

Sustainability (cont.)

- The WCED definition is good but… how do we quantify it?
- Sustainability Assets: Environmental, Economic, Social
- Need to contribute to all three to achieve strong contribution to sustainability (i.e., (system thinking).
- If profits depend upon selling/reducing/ consuming/destroying any of these assets, then business is not sustainable

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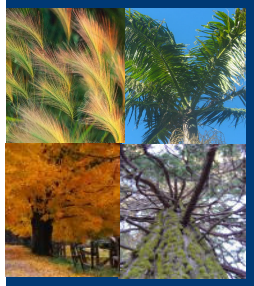

Sustainability (GHG)

- The most advertised issue related to sustainability: The risk of global warming due to emissions of greenhouse gases (GHG)
- Main GHG: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and F-gases
- Measured in terms of tons of CO_2 equivalent (tCO_2e)

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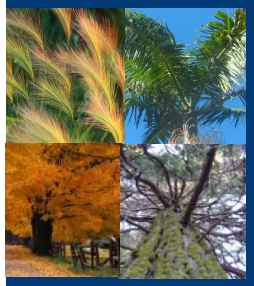

Quantifying GHG Emissions

- Convert to tCO_2e using the greenhouse warming potential (GWP) factor. 1 ton of:
  - Carbon Dioxide (CO2) = 1 tCO_2e
  - Methane (CH4) = 21 tCO_2e
  - Nitrous Oxide (N2O) = 310 tCO_2e
  - Hydrofluorocarbons (HFCs) = 140-11,700 tCO_2e
  - Perfluorocarbons (PFCs) = 6,500-9,200 tCO_2e
  - Sulphur Hexa-fluoride (SF6) = 23,900 tCO_2e

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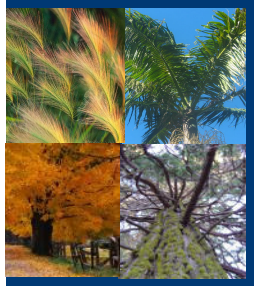

GHG Emissions Distribution

Source	Industrialized Nations	Emerging Economies	Poor Countries
Fossil Fuels (CO_2)	81%	41%	5%
Methane (CH_4)	11%	16%	21%
Nitrous Oxide	6%	10%	12%
F-gases (HFC, etc)	2%	0%	0%
Land use change	-	33%	62%

- The goal of the Kyoto protocol: to reduce GHG emissions to 5% below of 1990 levels by 2012

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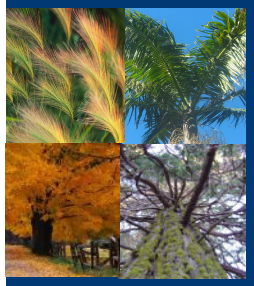

Sustainability (GHG)

- Mechanism of Reduction: Cap and Trade
- A cost-effective, market based mechanism for protecting human health and the environment
- How does it work?
  - Industrialized countries are assigned a maximum GHG emission per year
  - If emission<maximum allowed, excess can be sold in the open market
  - Buyers are those who could not meet targets
  - Emerging economies have no limits

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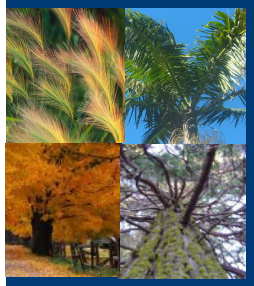
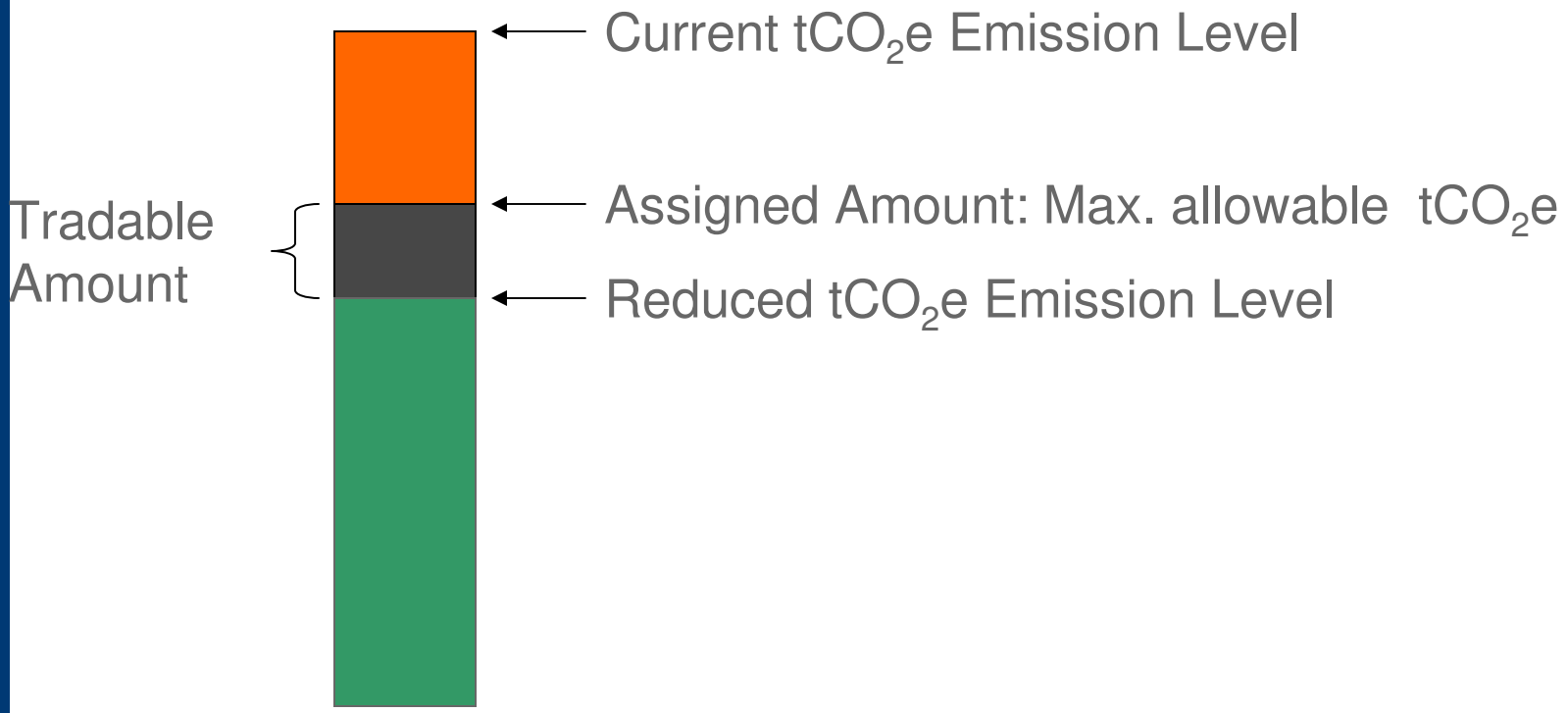


Cap and Trade Mechanism



- Result: The risk (technical) of global warming now has a market value

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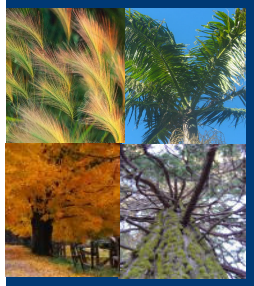
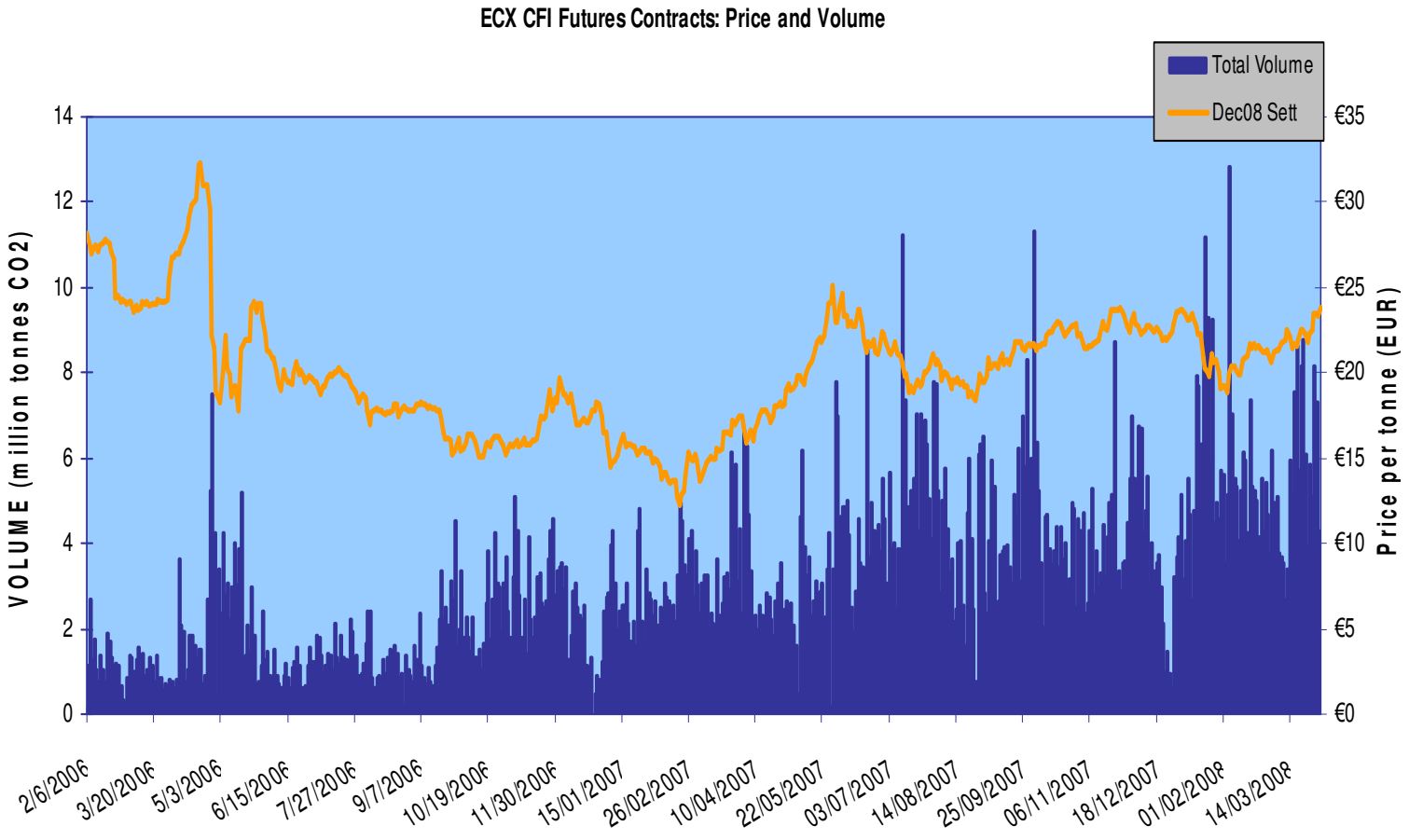


Market Price per tCO2e (Dec 08)



Now you see the connection??

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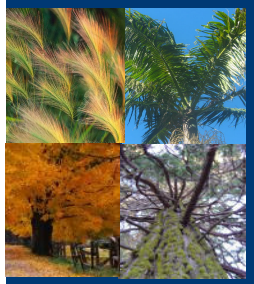
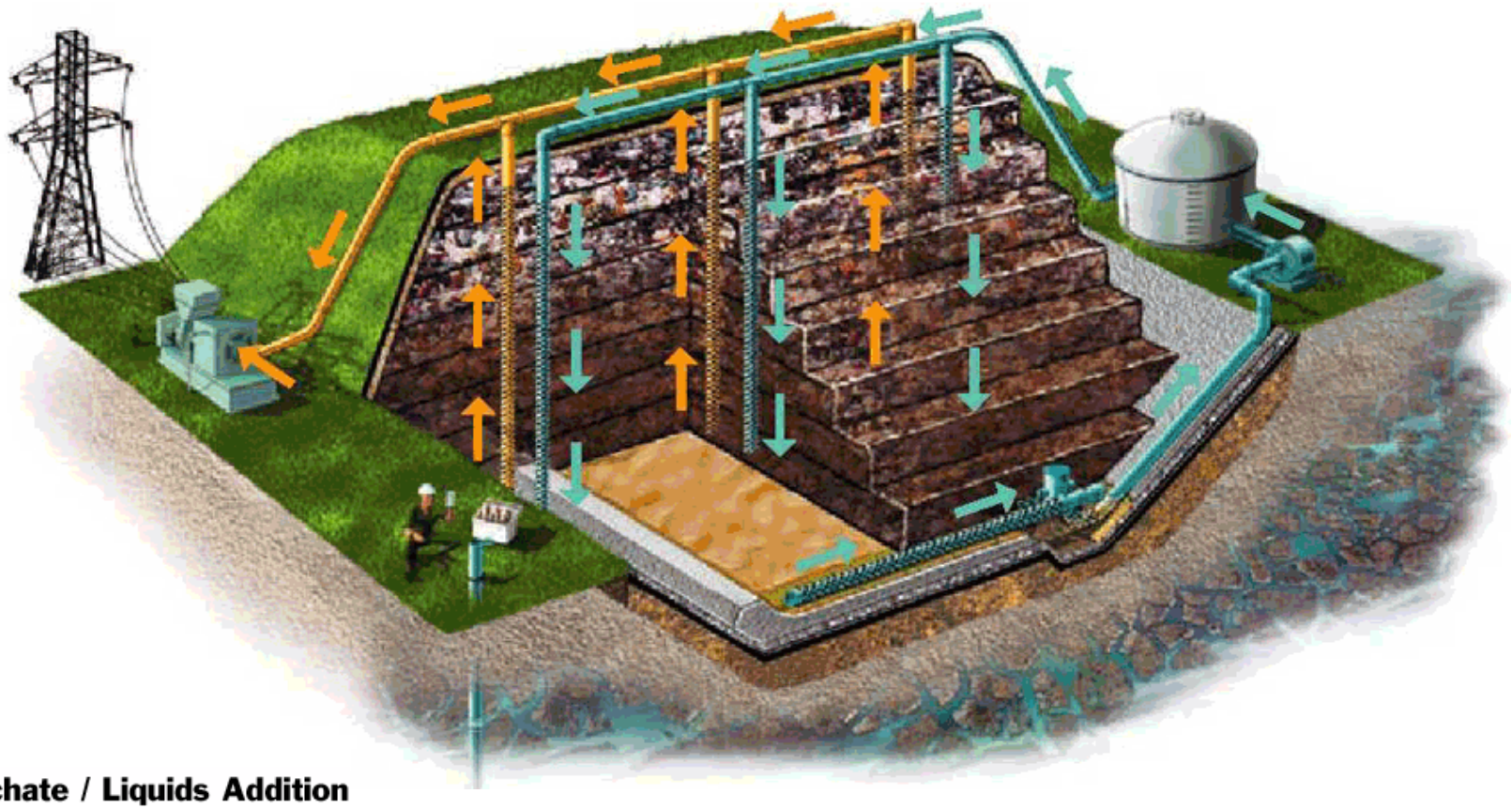


Where does Geosyntec fit in?

Landfill gas contains about 50% methane



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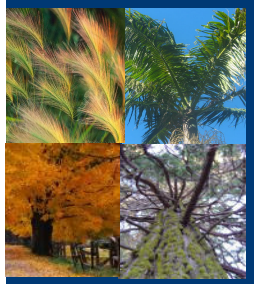

Carbon Credits for CH4 release avoidance

Destruction of landfill gas through Flares

Small (< 15 m^3/sec.)

Large (> 85 m^3/sec.)

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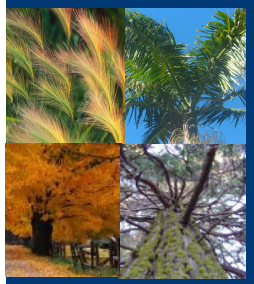
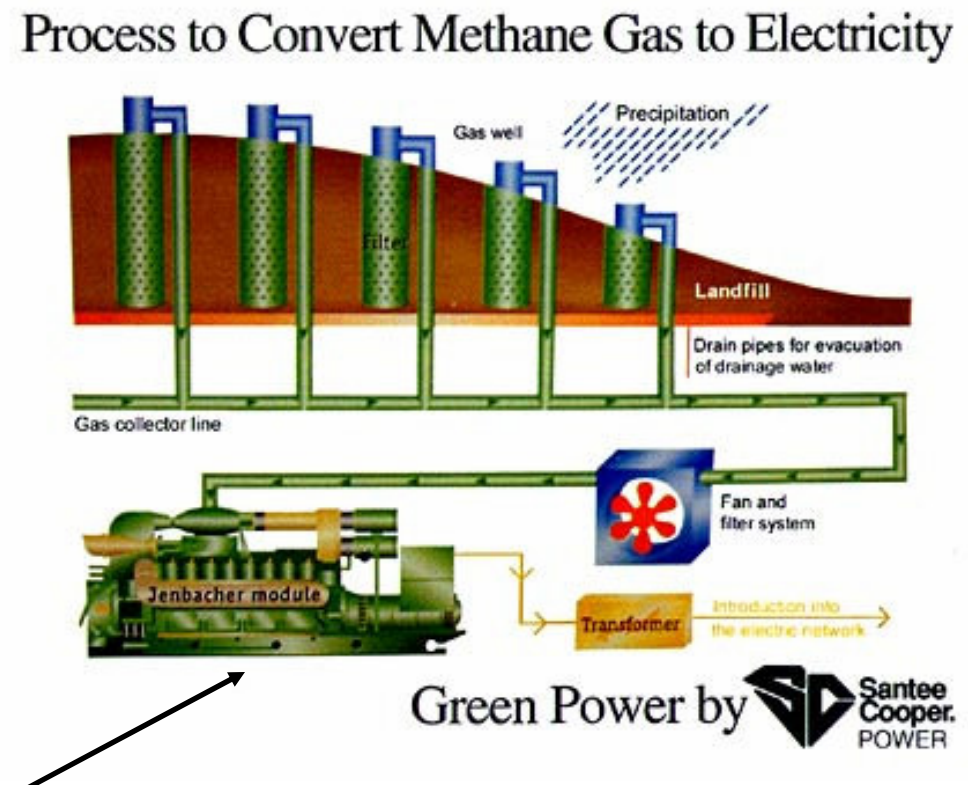


Credits for fossil fuel consumption avoidance

Landfill gas to energy projects



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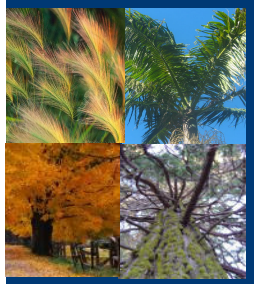
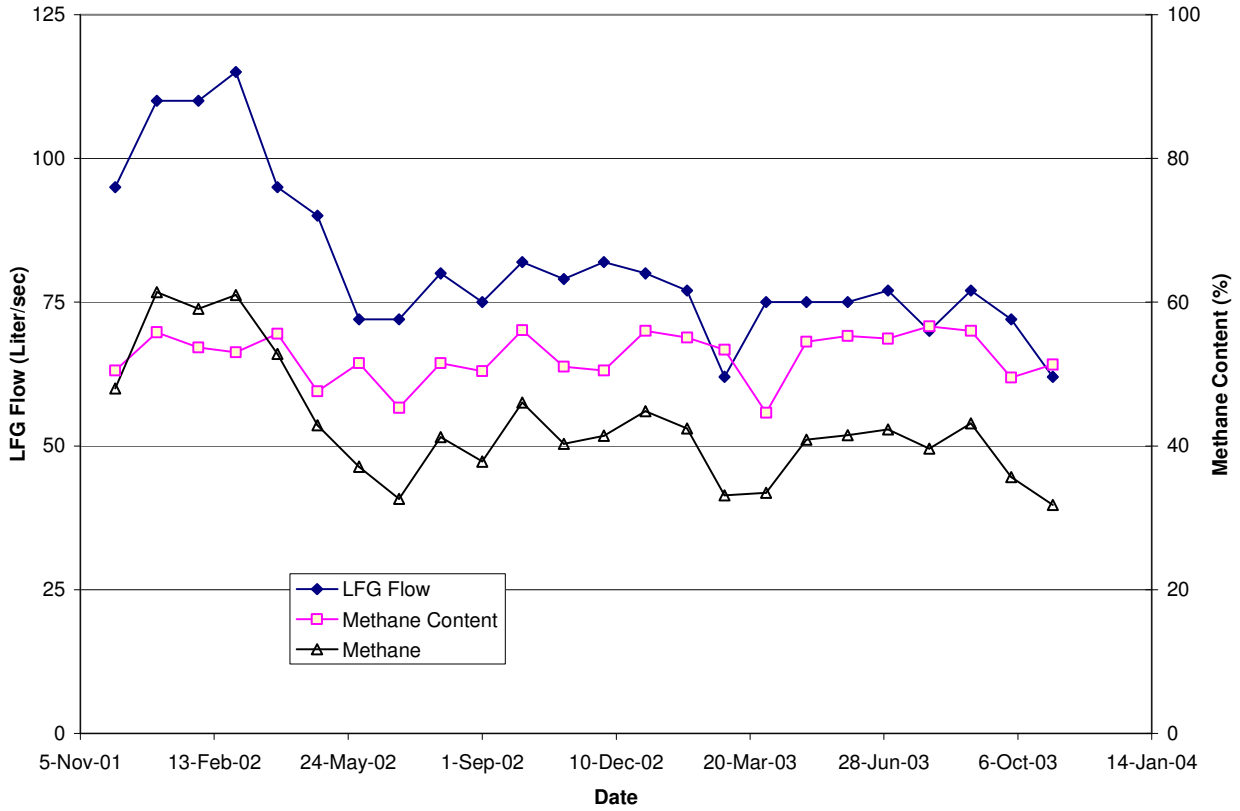


Amount of Methane in LFG

- LFG volumes varies with time



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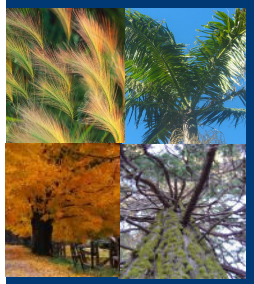

PROJECT RISK VALUATION

Option pricing allows us to price a LFG project risk associated with: The amount of LFG (technical risk) and the price of tCO2e (market risk).

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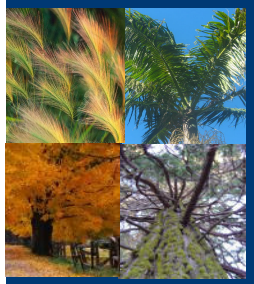

Sustainability-Summary (GHG)

- Society has put a price to global warming risk
- As a result, a technical risk (i.e., global warming) now has a market value
- Financial tools can be used to value technical risk
- As our understanding improves, more technical risk will become market risk through the process of securitization

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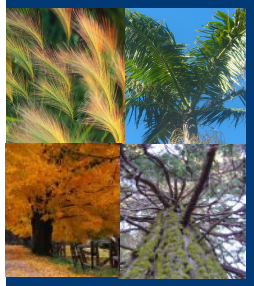

GHG is just one Sustainability Issue (J. Diamond, 2005)

1. Habitat destruction
2. Wild food decline (fish)
3. Biodiversity reduction
4. Soil erosion (10-40 times faster than soil creation, 500-10,000 faster on forested land)
5. Depletion of fossil fuel (oil, gas, and coal)
6. Freshwater underground depletion rate faster than natural replenishment
7. Limited photosyhthetic capacity
8. Chemical Industry
9. Alien species
10. **Green house gases**
11. Population growth
12. Increase of standard of living

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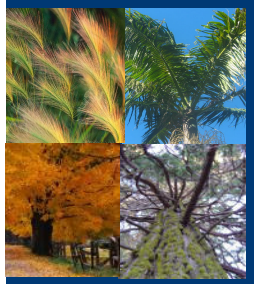

Acknowledgments

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The rest by:

The Espinoza Foundation (i.e., late nights, weekends, unattended parties, etc.)

Slide 29

D19 DEspinoza, 3/31/2007