Uranium and Phosphorus:

A "Cooperative Game" for Critical Elements in Energy and Food Security

Technical Meeting,
IAEA HQ, Vienna

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*Lead Technical Author

Our team photo : remember, remember the 5 November – was it gunpowder?

Background and Experience

- Regis Stana PhD (Technical Lead)
  - PhD Chemical Engineer
  - Westinghouse R&D (WMC): Development Work on Several Processes for Recovery of Uranium from Phosphoric Acid and other Sources (Including IX and Membranes)
    - Led Process Design Team for Full-scale Plant
    - Three Years at Operating Plant
  - Hired By IMC in 1981 to "Fix" their Uranium Recovery Plants
    - One Complete Plant at New Wales
    - Two First Cycles at Two CF Plants)
  - Plants Operated Profitably 1981-1993 (Contracts for U_3O_8 Ended)
  - Served as Expert Witness for W.R.Grace in Lawsuit by Uranium Recovery Corporation involving their Process for Recovering Uranium from Phosphoric Acid.

Background and Experience – Multidisciplinary Team

- Brian Birky PhD (Health Physics)
  - Joint Lead IAEA P Industry Safety Report
  - Director, Public and Environmental Health, Florida Institute of Phosphate Research, Co-PI "Stack Free" Phosphogypsum Project
- Julian Hilton DPhil (Policy)
  - Joint Lead IAEA P Industry Safety Report
  - Chairman, Aleff Group, Co-PI "Stack Free" Phosphogypsum Project
- Johnny Johnston (Agriculture)
  - Senior Lawes Fellow, Rothamsted Research
  - Lead Author, FAO P Review 2008
- Malika Moussaid PhD (Operations)
  - CEO, Aleff Group, Consultant/ Project Manager Cerphos Development Plan, OCP Group, Morocco

P Rock for Peace: Sustainability on Trial

- Mission: "peaceful, socially beneficial, economically viable, environmentally sustainable exploitation of a natural resource of limited quantity, essential for all life…"
- P Rock for Peace = Food, Feed and Energy
  - Phosphoric acid (P_2O_5)
    - DAP, MAP, DCP,
  - Recovered Uranium (U_3O_8)
    - Energy for developing economies
- Follow the P life-cycle "Earth to Earth"

Drivers and Constraints

- Food security
  - Access
  - Prices
  - Concerns about long-term build up of residues in soils, eg heavy metals, radionuclides
- Energy security
  - Competition for land (food crops or renewable energy crops)
- G20 – the new economic order
- Demographics – the new world aged 25 or younger
- Recent failures of the market economy
- Extreme price volatility, eg P fertilisers, U, sulphur

Is the management of essential resources such as P and U too significant to entrust solely to the market?

Or should there be a concerted national and international plan to manage such resources in a strategic manner to benefit all and to reduce the likelihood of future conflict over access to critical resources?

Opportunity: U recovery from P_2O_5

This is the third wave

(1. 1960s, 2. 1970s, 3. 2010s?)

But at a unique moment in the evolution of the phosphate industry

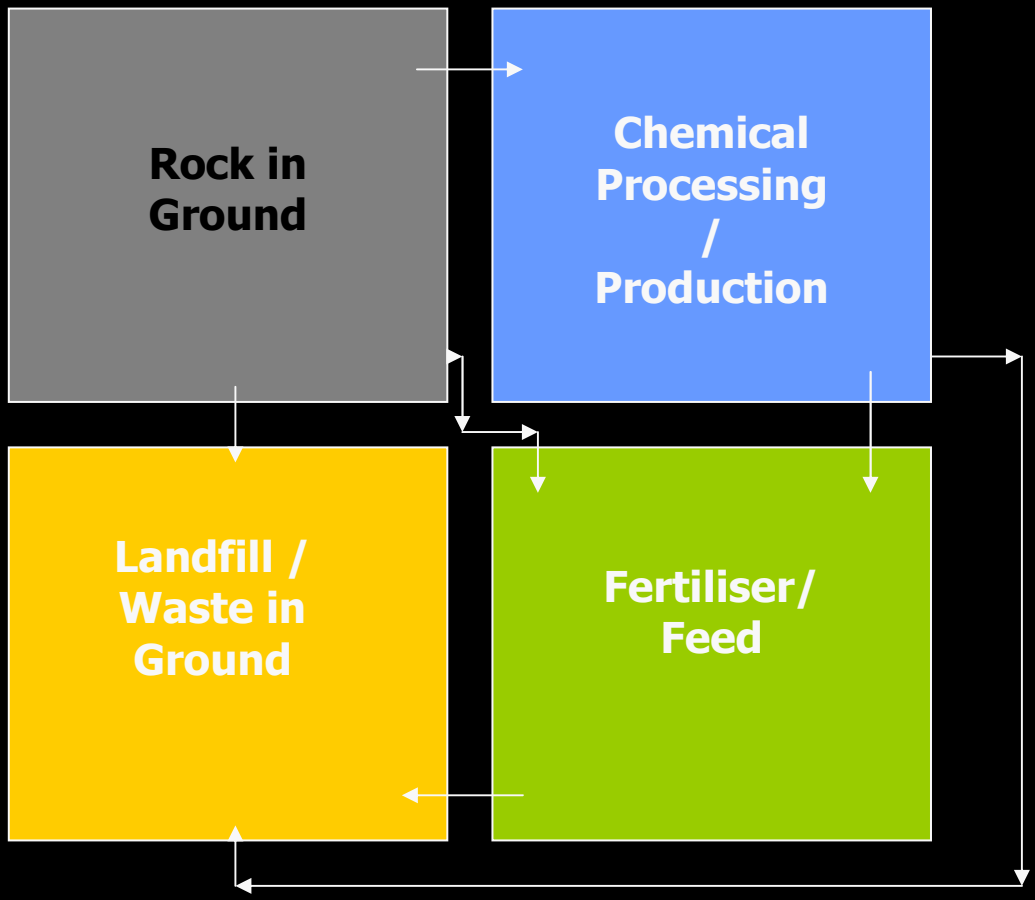
- Move from US/EU to BRICS and emerging economies
- Different perspective on management of key resources, such as P and U
- Relative lack of knowledge and experience
- Relative lack of constructive regulatory framework aimed at economic and social development

Triple Bottom Line Returns:

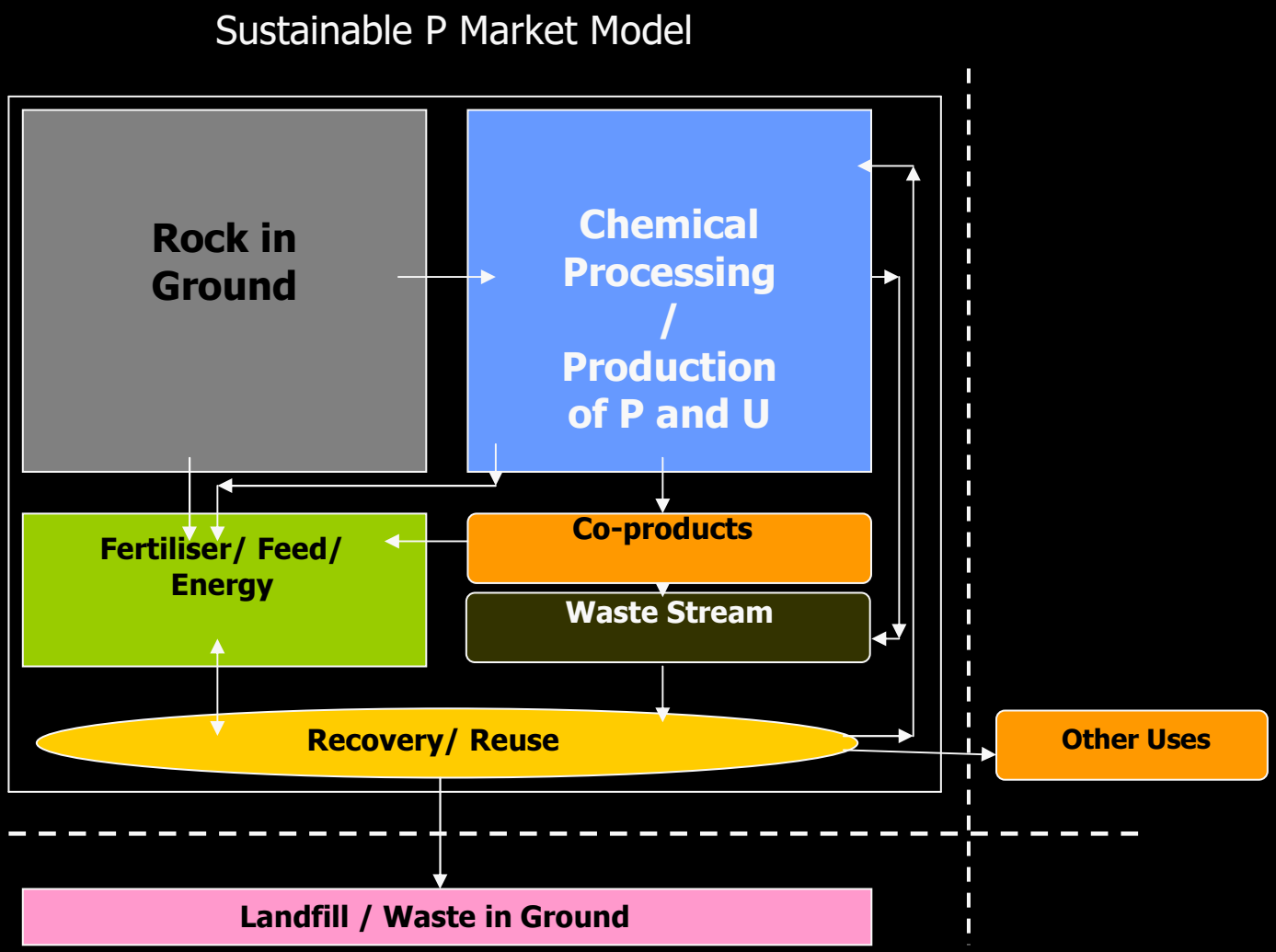
1. Economic 2. Social 3. Environmental

P and U as utilities not commodities…managed under a new social contract for “win/win”?

P Life-cycle Quadrant Model (Commodity)



P/ U Life-cycle Quadrant Model (Utility)

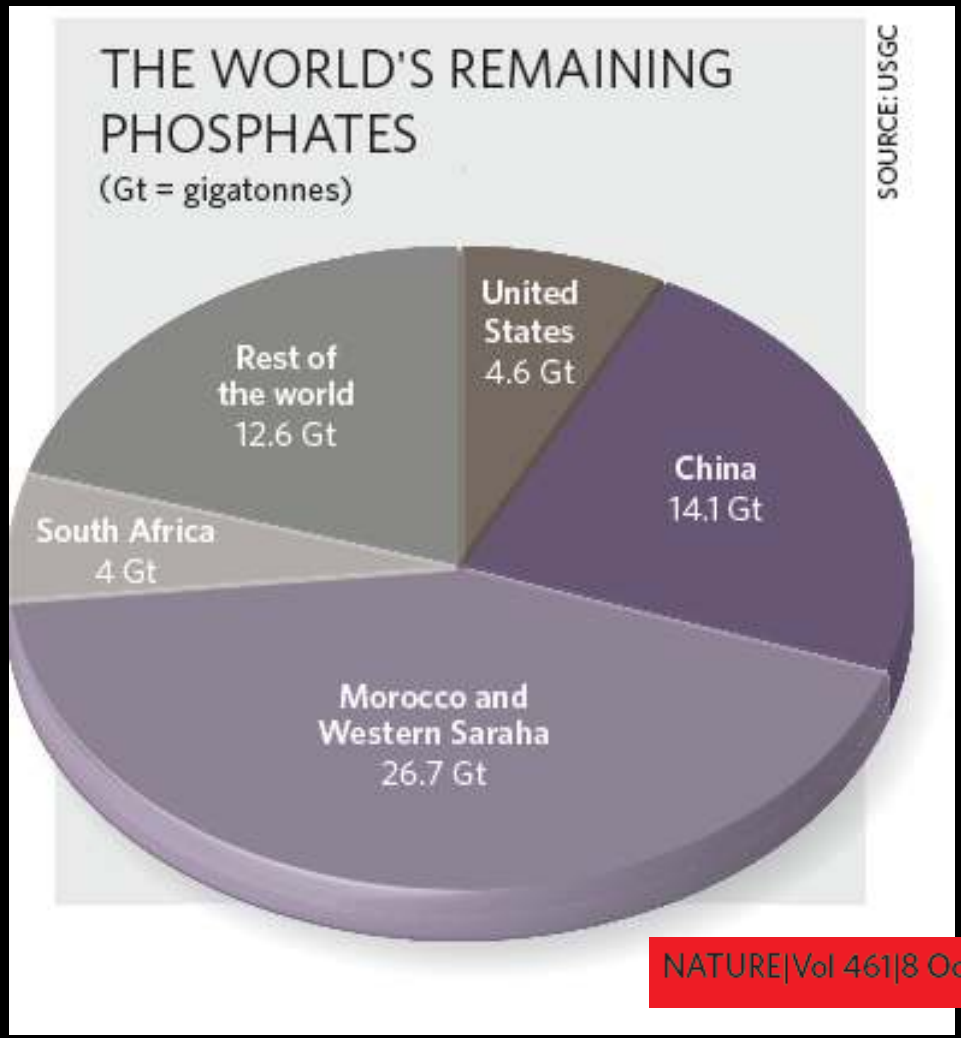


P_2O_5

A Potential Major Unconventional Source for Uranium

- Phosphate Deposits Contain Uranium
  - Nature and value of deposits in phase of extreme transition
- A well-tested additional cycle in P acid production
  - Range: 0.1-7 Kg/Tonne of P_2O_5
  - Typically: 0.3-0.6 Kg U per Tonne P_2O_5
  - Price: Volatile, but in 2007, U_3O_8 Reached $300/KG
  - Currently $ c.100/Kg on Spot Market and $150/Kg for some Long Term Contract

P Reserves: How much is there? … A Dark Art?



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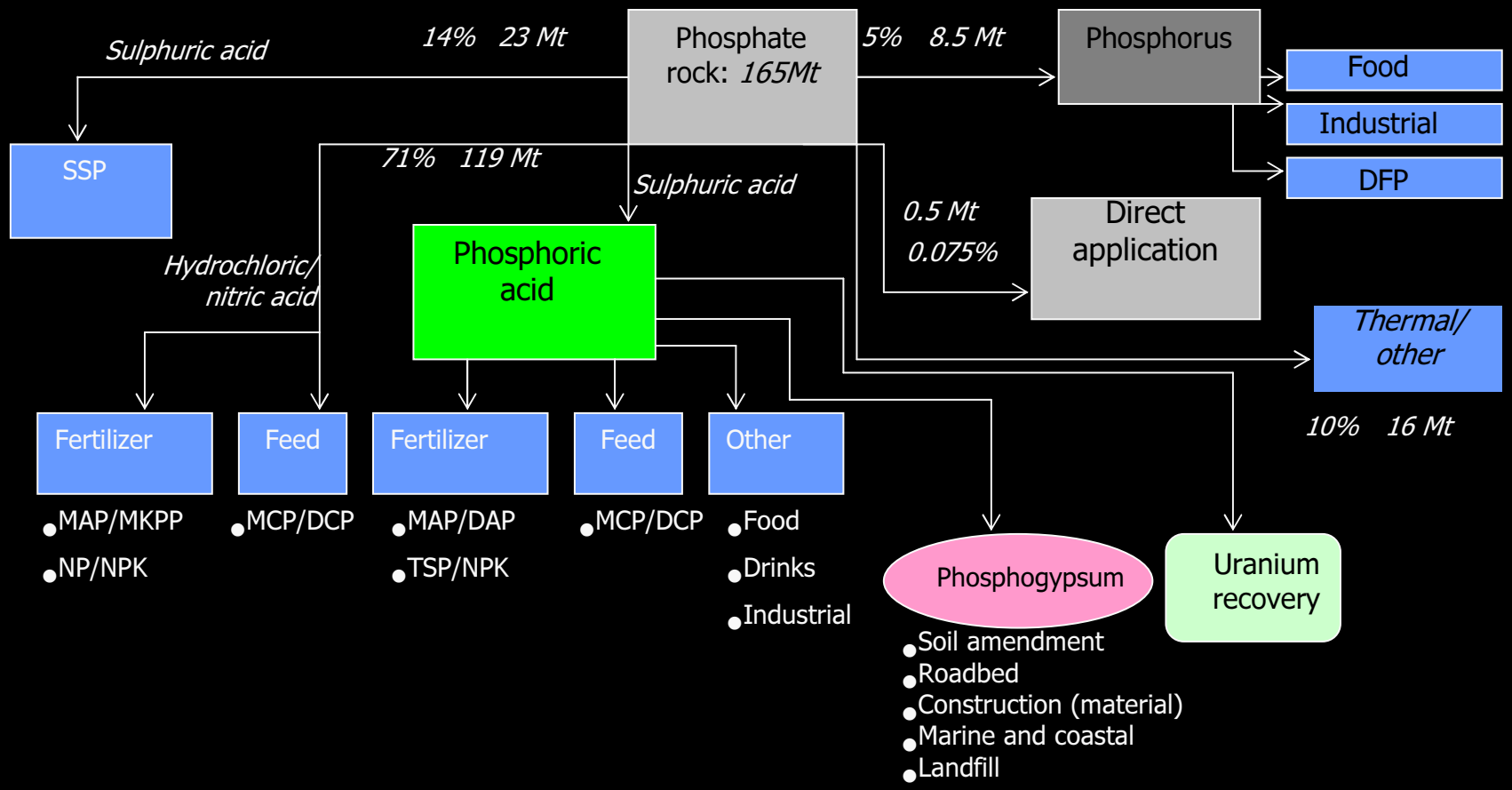
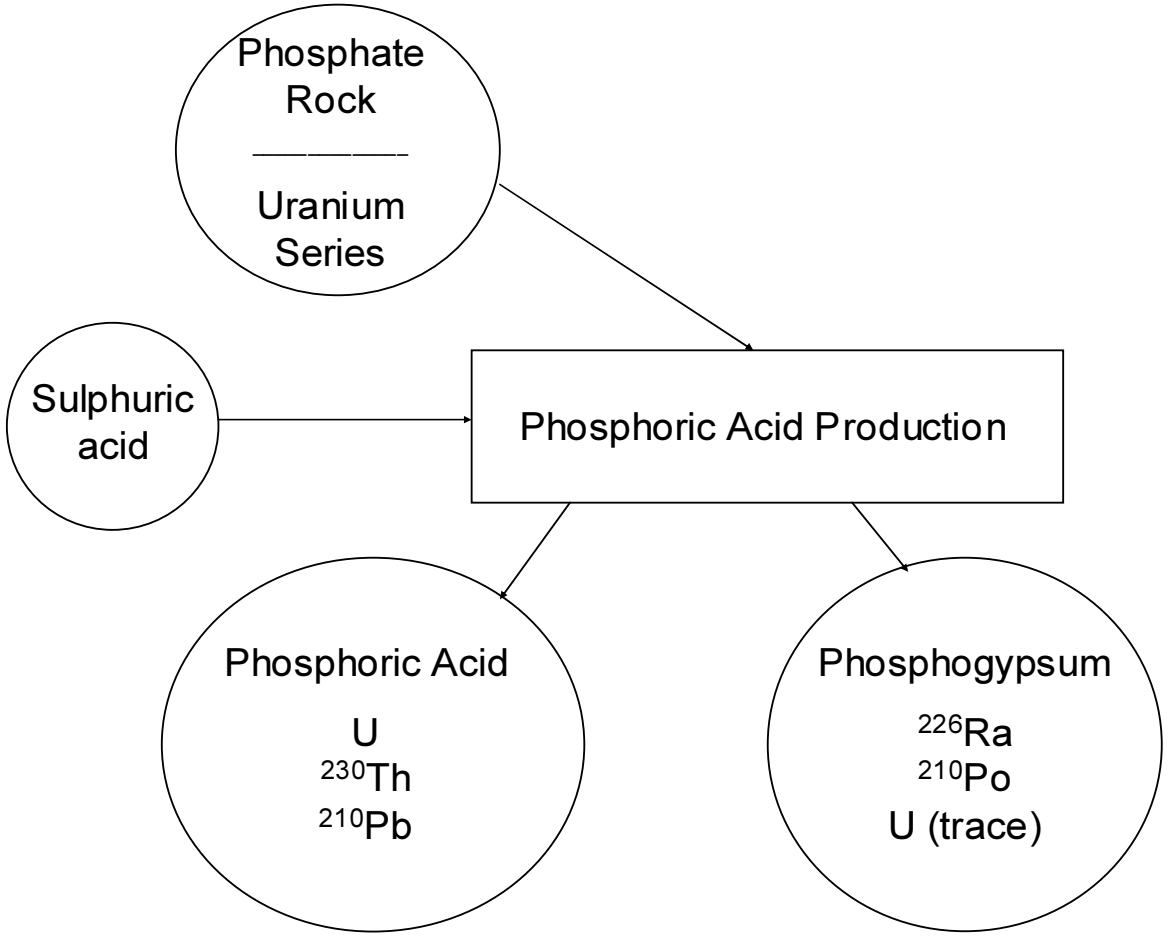
Phosphate Rock Utilisation Streams



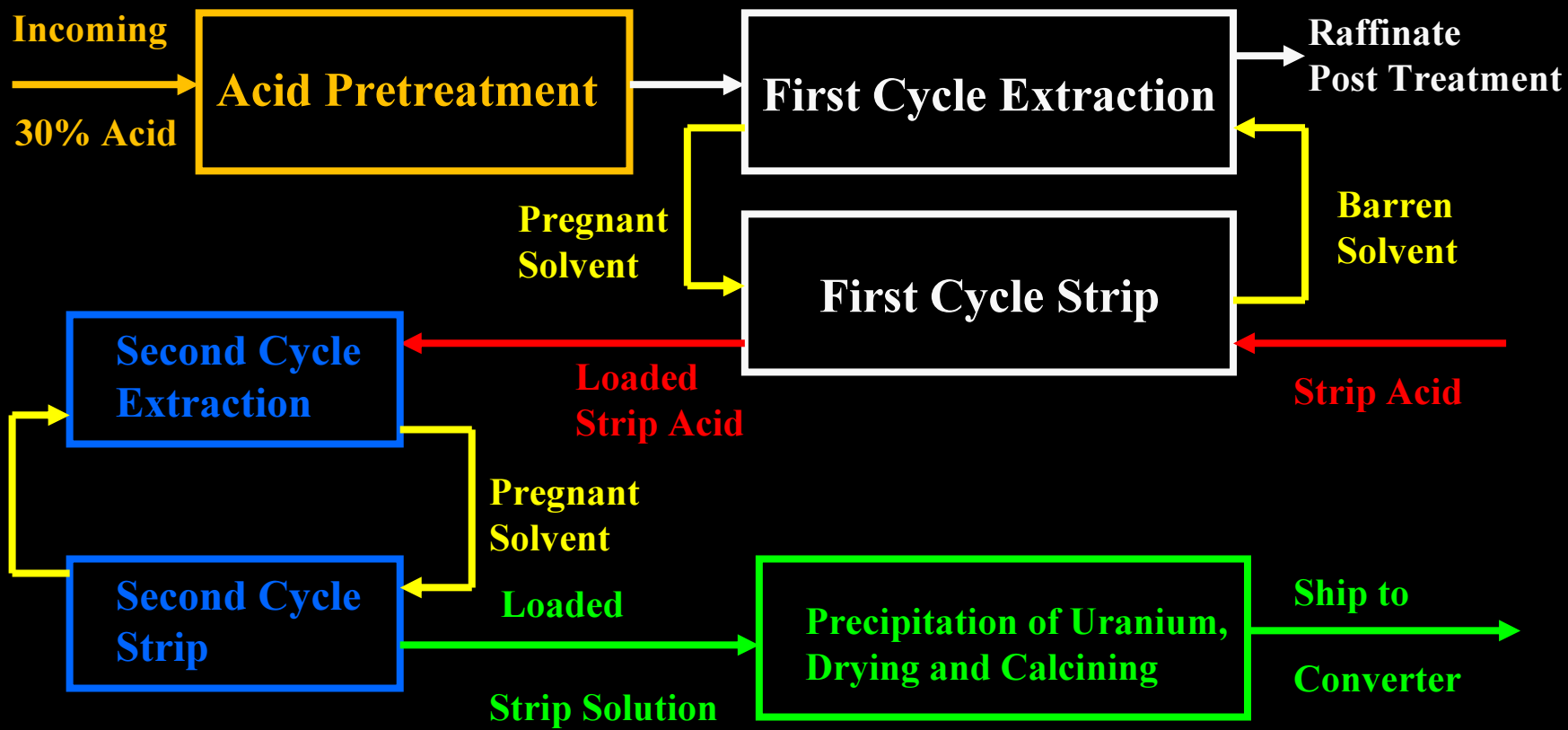
How Long will Known P Last?

150-250 Years at present rates of depletion, time-frame shortening…

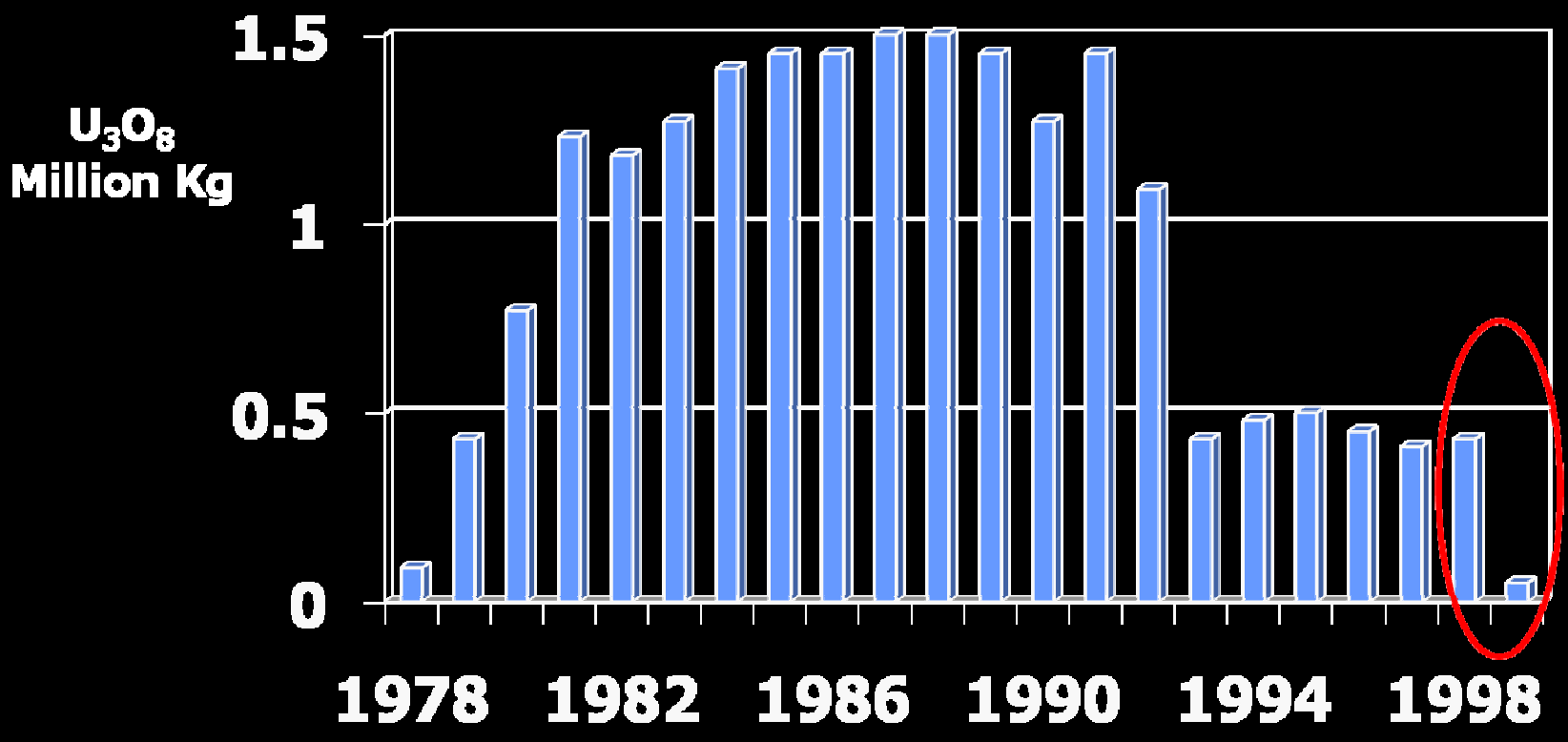
Partitioning of Radioactivity in Wet Process Phosphoric Acid Production [ref]



Flow Sheets: USA – Wave 2 Plants



Uranium Recovered from P_2O_5
USA Wave 2: 1978-1998



Experience to Date

- Quantity: c. 20 million Kg of U_3O_8 has been Recovered from Phosphoric Acid
- Lifecycle: Many Plants Operated for 10 Years+
- HSE: No Significant Issues to Date
  - Elimination of TLD Badge after Urine Analysis
  - Minimal Health Physics Requirements - Refinery Building Only
- Markets: CF, Mosaic and Morocco Have Announced that They Are Considering Building Uranium Recovery Plants

Life-cycle Cost Analysis:
Opportunities to Reduce Cost of "Next Generation" Plant

- Each Previous Plant had Strong and Weak Points
- Applying Lessons Learned will Reduce both Capital and Operating Costs
  - Solvent losses varied by a factor of 3 +
  - Pretreatment Costs Varied by a factor of 3 +
  - Total of Solvent Loss and Pretreatment varied by a factor of 3 +

Opportunities to Reduce Cost of "Next Generation" Plant

- For Example
  - Average Solvent Concentrations in the Raffinate Ranged From 5 ppm to 100 ppm
  - Strip Coefficients Ranged from 15 to 150
  - Solvent Loss Due to Settler Cleanings Ranged from <.02 to >0.1 Kg/Tonne P_2O_5 Processed
  - Some Plants had Negative Impact on Fertilizer Production, Some Had Positive Impact

Estimated Capital Costs: New Generation Plants

- Capital Costs (inflation adjusted)
  - Estimated lower than for previous generation Plants
  - Highly Dependent on Flow Sheet Adopted
- Cost Driver – Equipment Selection: In all Previous Generation Plants
  - Significant unnecessary components, resultant on poor design
  - Replaced/ replaceable with less expensive items

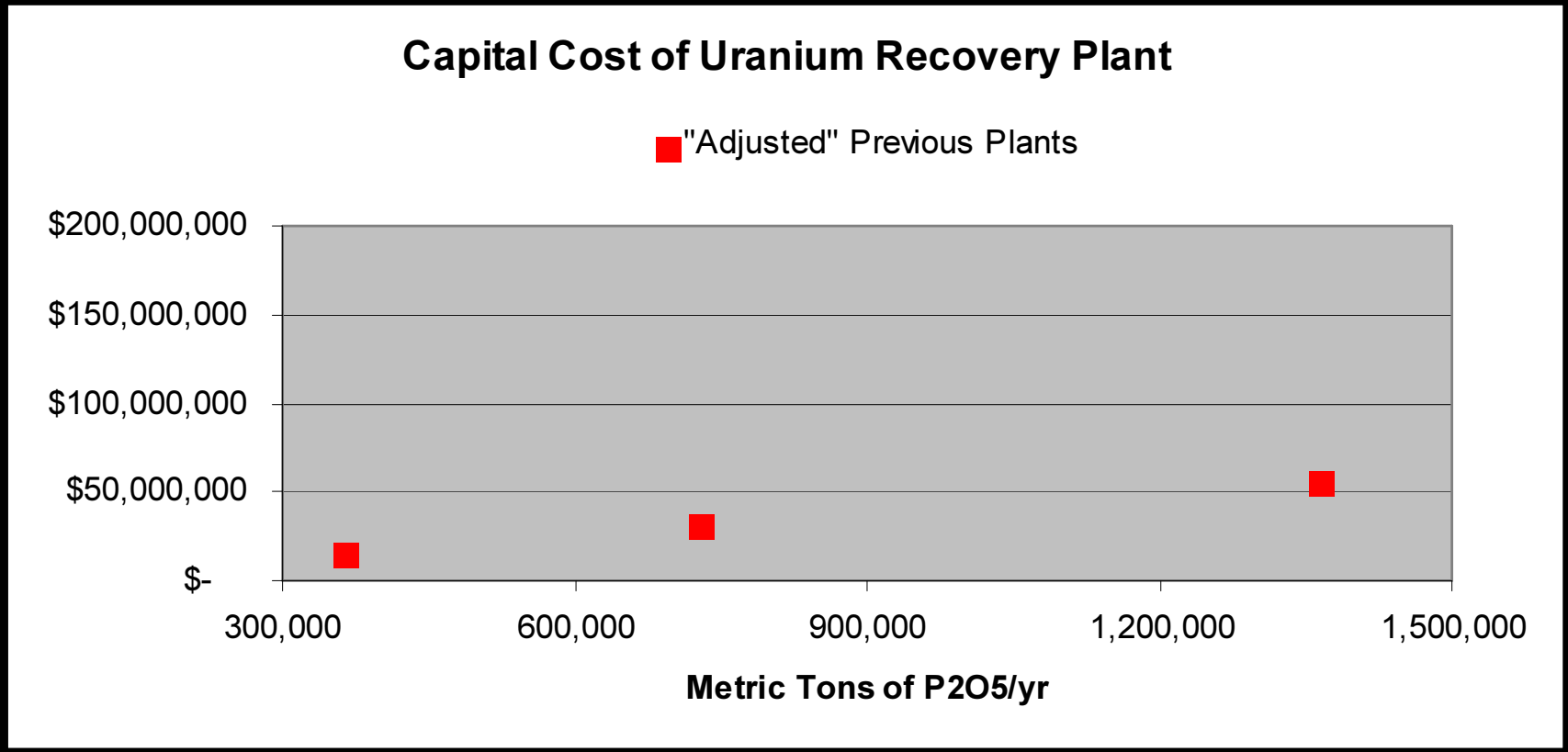
Estimated Operating Costs: New Generation Plants

- Projected - less than $40/Kg
- Cost Contingencies:
  - Uranium Content of Rock
    (In USA, 0.45 Kg/Tonne projected 2010-2020; previous estimated 0.35-0.4 Kg/Tonne)
  - Consumables
    - Solvent (trend higher)
    - Electricity (trend higher)
  - Labour (trend higher, but with potential offset with automation)
  - Regulation (negative externality)

Break-even Point

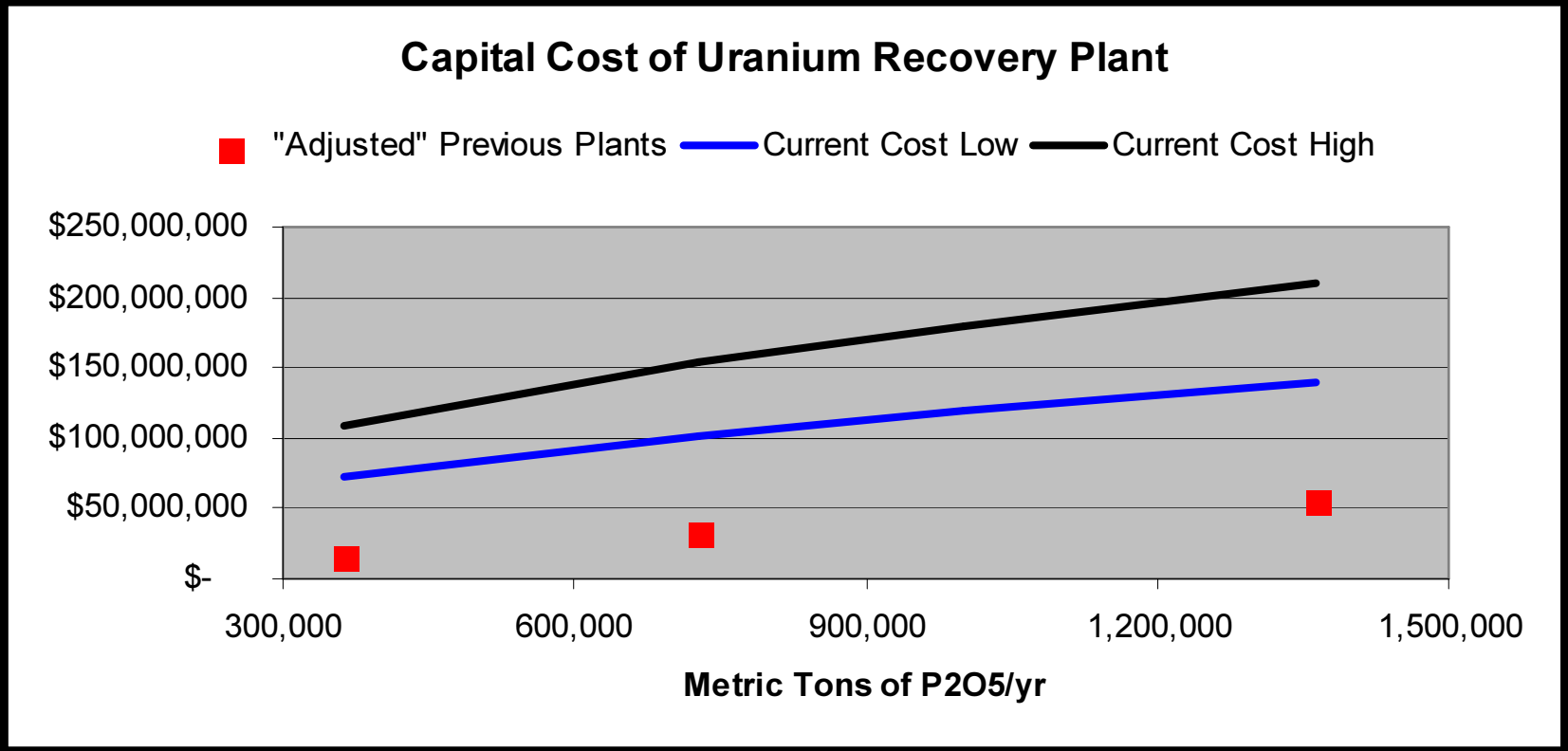
As a Rough Rule of Thumb, at a Uranium Price of $ 100 /Kg, any Plant That Can Produce at least 200,000 Kg U_3O_8/yr Should Give a 10 Year Pay Back

Capital Cost vs Plant Size



Previous Plant Costs Adjusted for Equipment Not Used

Capital Cost vs Plant Size



Previous Plant Costs Adjusted for Equipment Not Used

Uranium Recovery Plant: Build Timeline

1. Flow Sheet: 3-6 months
2. Cost Estimate: 3-6 months
3. Permitting: 6-18 months, in parallel with 1 and 2
   - Very little waste generated, but agreements needed on storage/ disposal
4. Detailed Design: 6-12 months
5. Construction: 12 months
6. Start-up: 1-3 months

- Total time: 25-45 months
- Total Capital: $70,000,000 – $200,000,000

Win/ Win: Recovering Uranium - Futureproofing

- Slow or Eliminate Uranium Build-up in the Upper Soil Horizon…
- So Help Prevent Eventual Long-term Catastrophic Consequences for Food Security
- Recover, Use/ Stockpile an Essential / Strategic Energy Resource

Multi-dimensional issue requiring multi-disciplinary responses – we must talk to, and learn from, each other…

Morocco (1) - Context

- Critical point in the evolution of the national economy
- P is the key industry (40% of all foreign earnings, 5%+ of GDP)
- To date only medical and related uses of nuclear materials; small reactor at CNESTEN
- JV with Aveva on U recovery
- Predictable surge in national and regional demand for energy
- Win/win?

Morocco (2) – Possible Solution

- Wish to regulate is a "constructive" way, ie evidence-based, but contributing to economic and social development
- Proximity to Spain and France
- Human capital – COE (CNESTEN) and Industry Leader (OCP) well able to do this technically and financially
- Wish to align with international norms and laws, but also to foster national interest
- OCP has a conscious "Leadership" policy: this would be a very good issue to lead on

IAEA Group: Ideas for Future Work Plan

- Create organisational vehicle for cross-cutting cooperation and enable win/win outcome
- Evaluate alternative extraction technologies on "Level Playing Field"

  (Based on a Specific Plant or Group of Plants)
- Consider / Mitigate all Impacts,
  - Policy-driven delays and regulatory constraints
  - Loss of Institutional Memory (Average Age of "Experts" is >70
- Publish on-going Triple Bottom Line Analysis based on Full Life-cycle Cost Analysis
- Train competent future operatives based on past and current experience (preserve organisational memory)

شكراً

Thank you

Danke

Merci

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What About Phosphoric Acid Plants that Use the Hemi Process?

- Even if the Uranium Content is about Half
- Since the Acid is ~40% P_2O_5, Uranium Content in g/l is Similar to Central Florida
- Octyl Phenol Phosphoric Acid Solvent has Been Demonstrated to Work Effectively in Lab
- Operating and Capital Costs will be about the Same per Kg as Central Florida (But Less Kg Produced)
- Piloting is Probably Required

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