

UNFC 2009: E Axis and Comprehensive Extraction (CX)

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Alignment of the Principles of Sustainable Development and the “Triple Bottom Line”

With the E Axis



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Changing the point of equilibrium to an equitable balance of shareholder and stakeholder returns

**Sustainability =
Changing the Way We Collectively Look at
Resources ...**

Nothing goes to waste



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Triple Bottom Line (TBL) – Definition

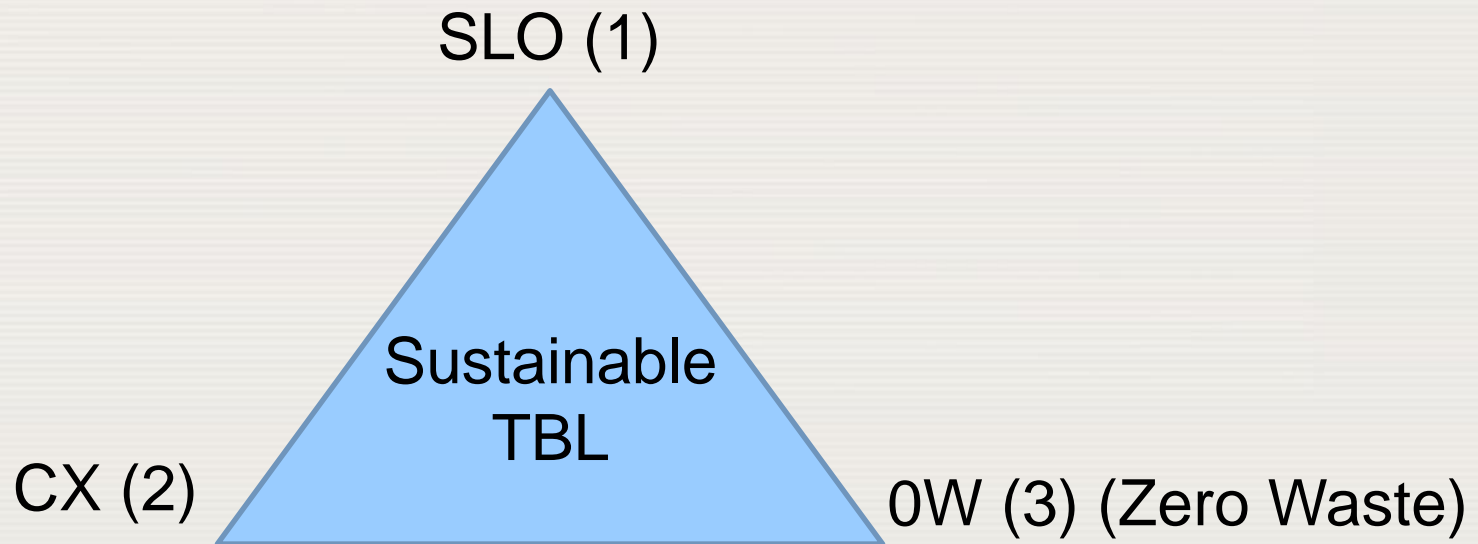
- Three components must all apply in equilibrium to enterprise or organisational performance:
 - Economic/ financial
 - Social
 - Environmental
- Introduced by John Elkington, 1994 in California Business Review¹
- Direct response to the Brundtland/ Sustainability agenda – becomes an enterprise obligation
- Derived from John Nash's Nobel prize-winning cooperative game theory – the “win/win”² equilibrium
- Goes well beyond Corporate Social Responsibility

1: ELKINGTON, J., "Towards the sustainable corporation: Win-win-win business strategies for sustainable development", California Management Review 36, 2, 90-100, (1994).

2. NASH, J., Non-cooperative Games, *Annals of Mathematics*, 54, 286-295, (1950).

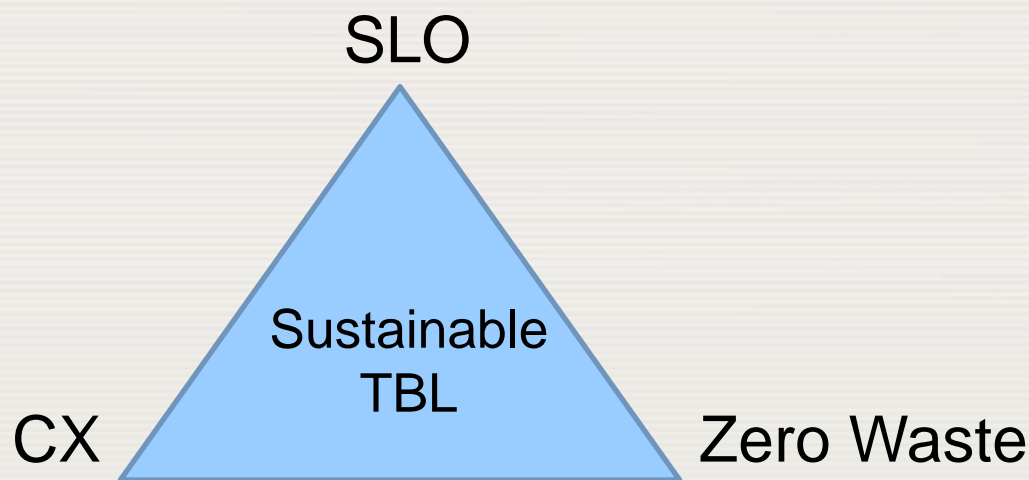
Aligning core “TBL” Principles with the E Axis: UNFC and Sustainability

- TBL 1 - Social licence to operate (SLO) (**social**) [ref Kathryn Campbell; Michael Lynch-Bell]
- TBL 2 - Comprehensive extraction (CX) (**techno-economic**)
- TBL 3 - Zero waste (0W) (**environmental**)



Core “TBL” Objectives; New Business Models

- De-risked financials/ ROI (protects lender/ investor)
- Stable, equitable, long-term partnerships with stakeholders
- Reduced risk of project-related social conflicts/ conflict-free supply chain/ compliance with EITI objectives
- Reduced impact on health, culture and heritage
- Equitable balance of economic and environmental interest



Comprehensive extraction

- **Disturb the ground once... extract everything of value in one pass**
- The term “comprehensive extraction” was (re)introduced by Dr. Pingru Zhong (China) during an IAEA UxP Technical Meeting, September 26-30, 2011
- Roots in Russian and Chinese research, 1990s (R. Villas-Bôas)
- 70% of mine tailing presently seen as a resource for one commodity or other
- Brought into currency during the follow-on Training Workshop, Marrakech, October 31 – November 5, 2011
- Focus on unconventional U resources, mainly Phosphates; but also applicable for copper, coal, oil shales ...
- Rethink the flowsheet... rethink the outcome
- Includes residues and tailings...
- Already happening ...

See: **New 'Comprehensive' Approaches to Uranium Mining and Extraction**

<http://www.iaea.org/OurWork/ST/NE/NEFW/News/2011/repository/New-Comprehensive-Approaches-to-Uranium-Mining-and-Extraction.html>

Unconventional (Green?) U Resources

Deposit type/subtype	Resources UDEPO (tU)	Grade (ppm)	IAEA UDEPO deposits	World deposits
Porphyry copper	100 000	10-40	7	691
Peralcaline complexes	393 210	50-250	13	125
Carbonatites	122 342	30-300	11	848
IOCG	2 308 602	30-250	14	> 100
Lignite and coal	7 358 112	1-500	33	1600
Black shale	1 489 147	10-200	44	Several hundred
Phosphates	13 553 900	50-150	50	1635
Total	25 325 313		172	5 - 6000
Sea water	4 500 000 000	3.3 ppb		

U & REE concentration in phosphates

Country	Deposit	U (ppm)
Algeria	Djebel Onk	25
	Djebel Kouif	100
Australia	Duchess	80 - 92
China	Undifferentiated	10 - 39
Egypt	Abu Tartur	40-120
Israel	Arad	150
Jordan	Shidyia	46
Morocco*	Bucraa	70-80
	Khourigba	80-120
Peru	Sechura	47-80
Saudia Arabia	Ma'aden	25-85
Senegal	Taiba	64-70
Syria	Khneifiss	75
Tanzania	Minjingu	390
Togo		77-110
Tunisia		12-88
USA	North Carolina	41-93
	Central Florida	59-200
	North Florida	50-143
	Idaho	60-141

* U in phosphates estimated to be 6.5 million tonnes

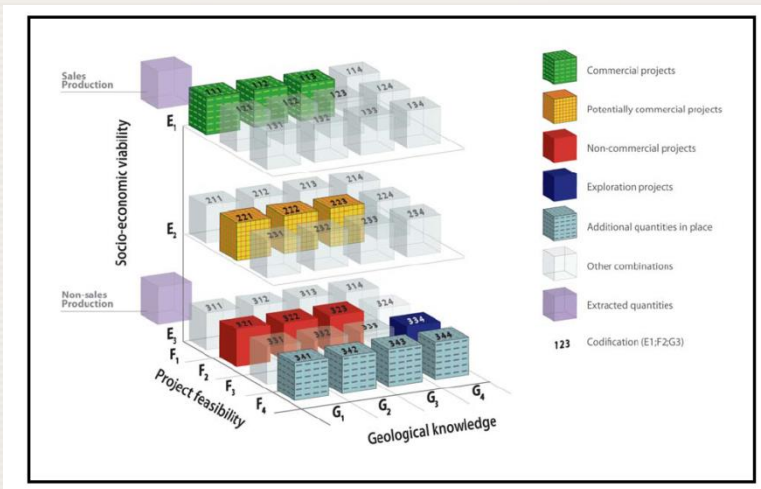


Phosphate rock source	Ln ₂ O ₃ (%)
Kola, Russia	0.8-1.0
Florida, USA	0.06-0.29
Algeria	0.13-0.18
Morocco	0.14-0.16
Tunisia	0.14
Quebec, Canada	0.18
Ontario, Canada	1.59% (La ₂ O ₃ +Ce ₂ O ₃)
Northern China	1.5 – 6.41 (Total R ₂ O ₃)

- In the estimated 70 billion tons of phosphate deposits within the Tethys realm, REE concentration averages 300 ppm.
- This translates to 2.1 billion tons of REE resources.
- It has been experimentally proven that REE also can be extracted along with U using appropriate solvents.

Operationalizing sustainable development

- **Closed (renewable) systems where possible:**
 - Efficient use of inputs – Energy, water, chemicals
 - Optimisation (and use) of all outputs including residues and tailings
 - Waste elimination/ waste as designation of last resource
 - Recycling and reuse
- Accurate and transparent management of essential materials (Natural capital/ geological endowment, EGRC-3/2012/INF.1 N.34)



UNFC – 2009 provides the framework for assessing projects and accounting materials throughout the life-cycle

Assessing comprehensive extraction (CX)

Quantities associated with known and potential resources

Contained in Ore concentrates/Phosphoric acid/other intermediate products

Not extracted; available in Wastes/PG process water

Available in raffinate and slags

Available in tailings and clays

Not Commercial for current extraction

Potential for Commercial extraction

Commercially Extracted quantities

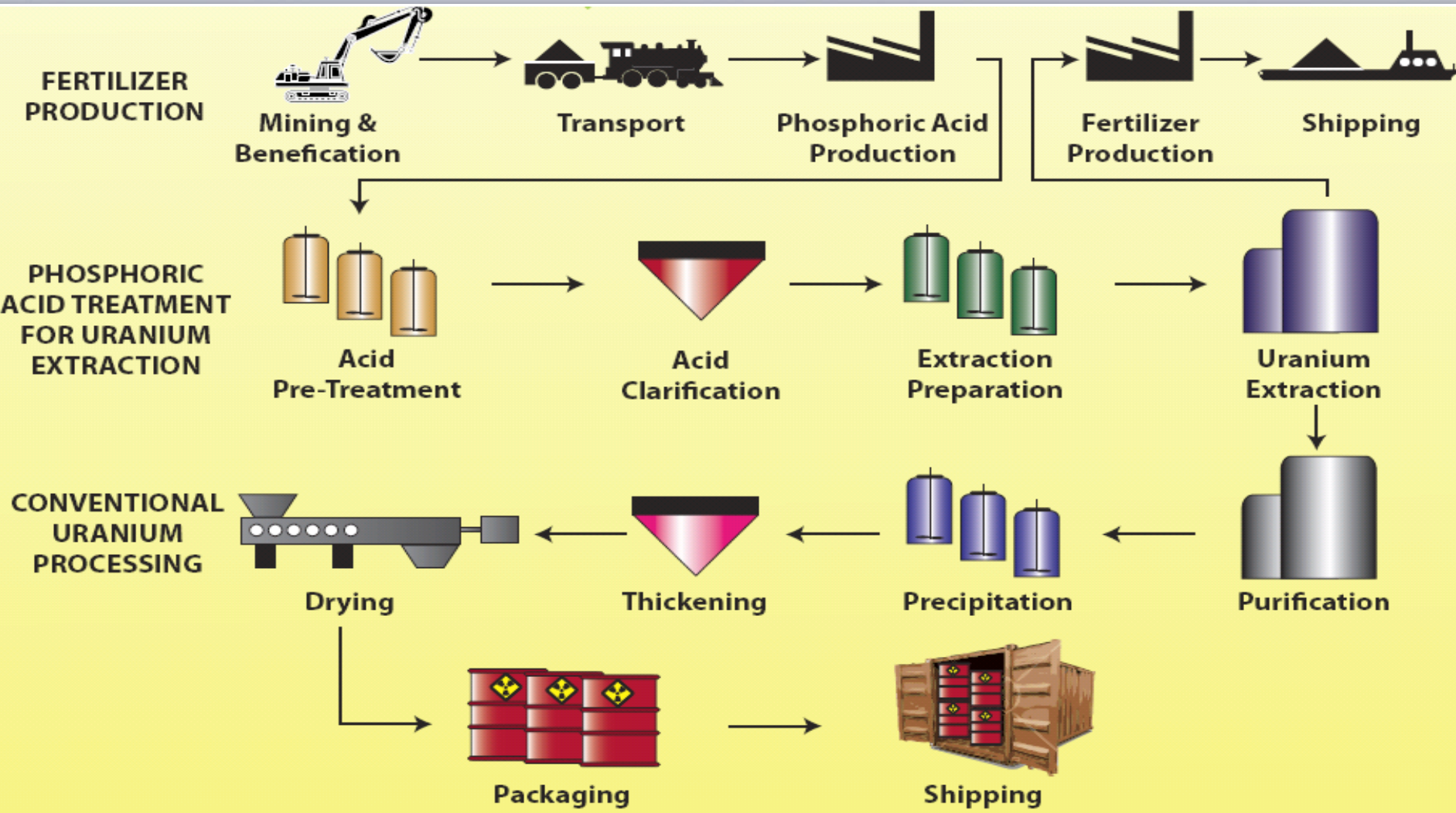
Dissipated in products, wastes, environment

Accurate and transparent management of essential materials

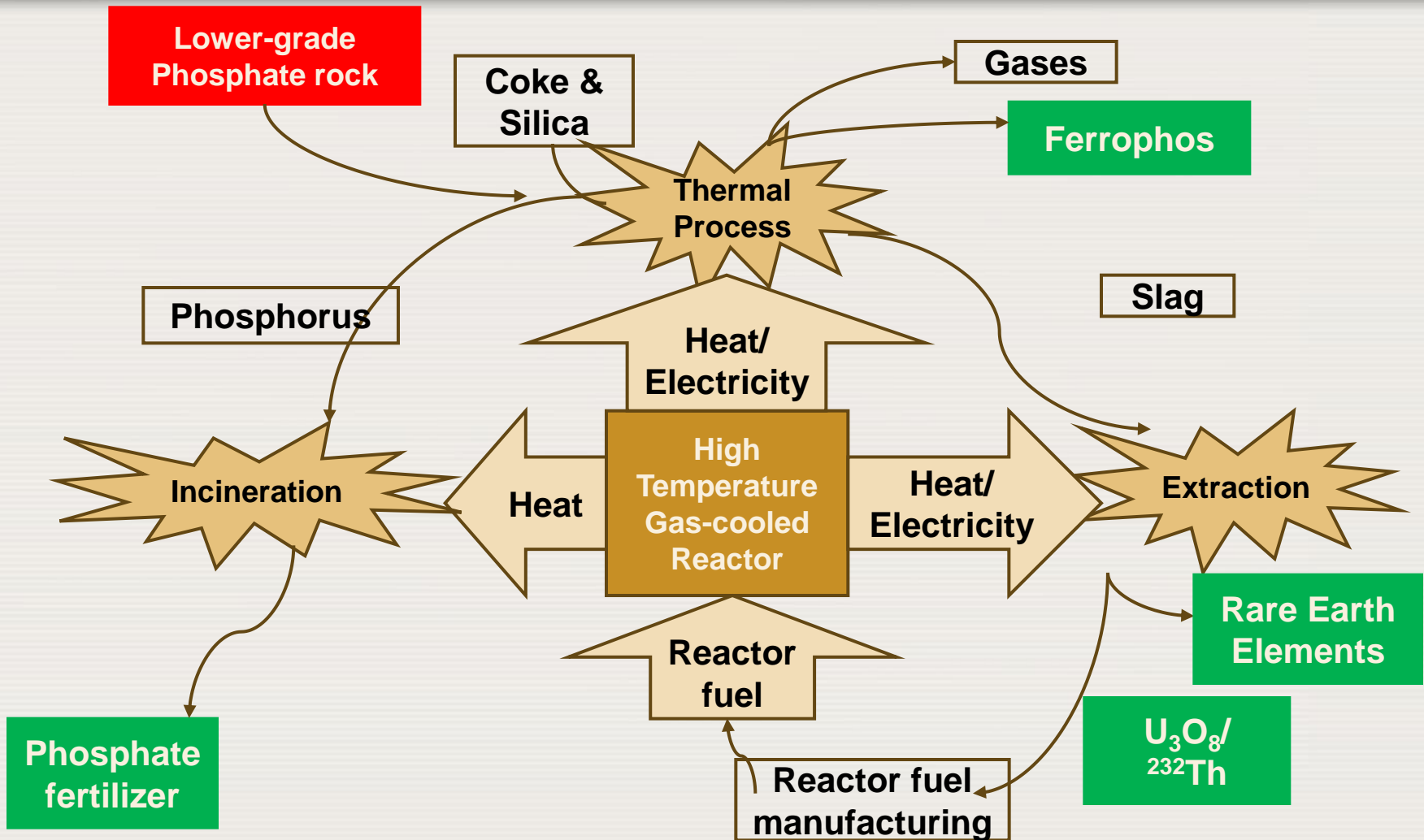
TBL 2 - CHANGING THE BUSINESS MODELS

COMPREHENSIVE EXTRACTION

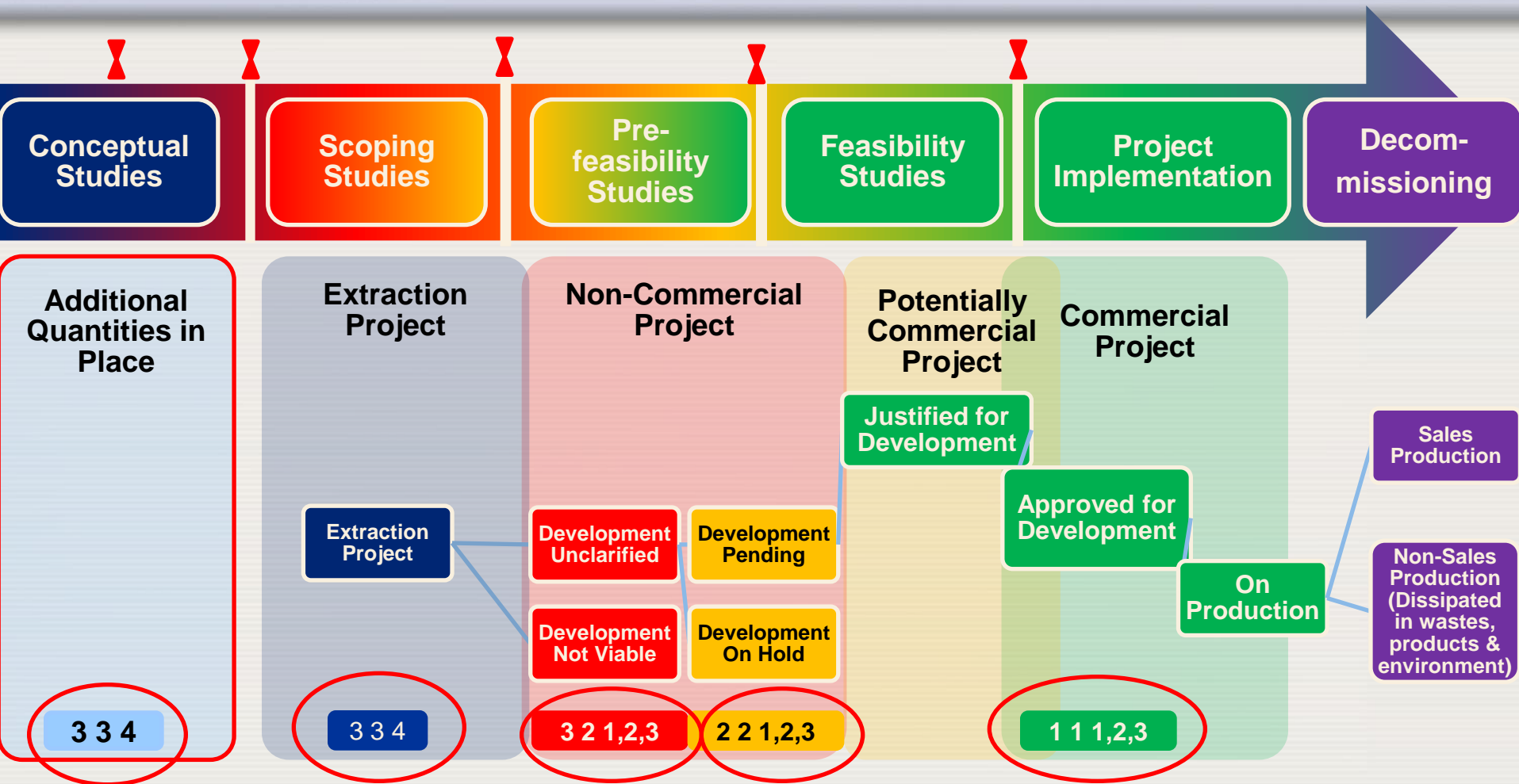
Solvent extraction for U as P by-product



Energy-neutral Phosphate Fertilizer Production



Comprehensive extraction lifecycle

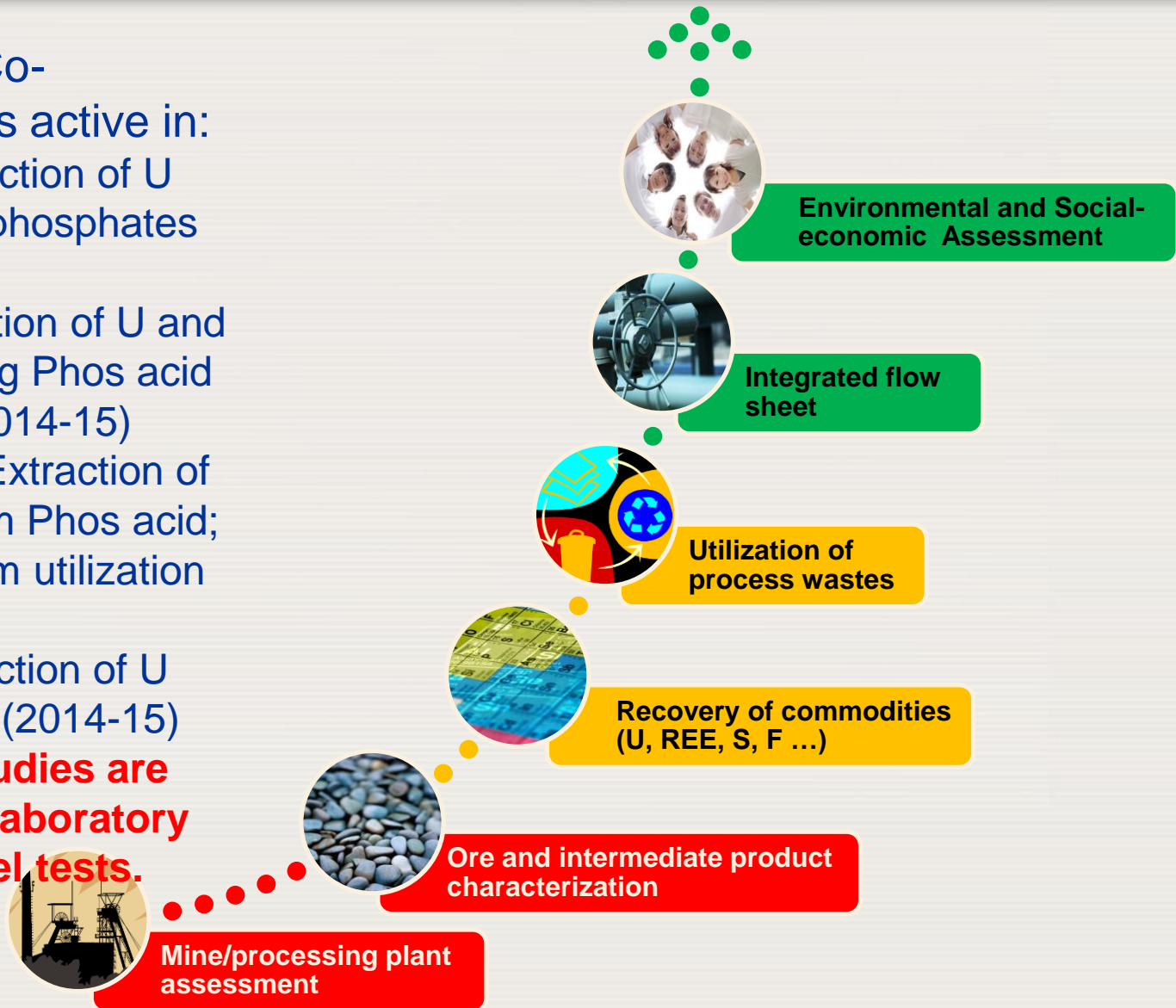


Accurate and transparent management of essential materials throughout the lifecycle

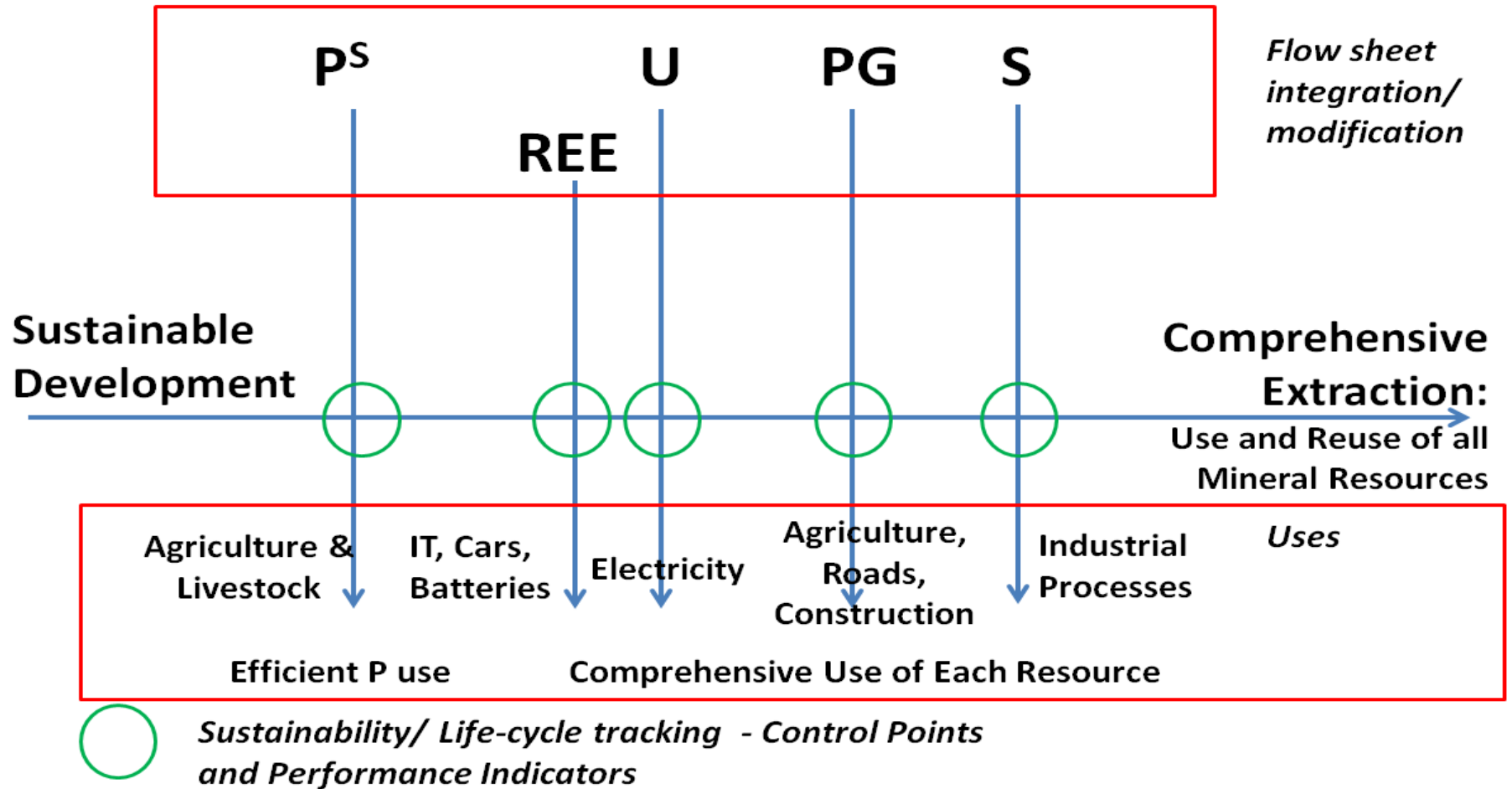
Conceptual CX Study

IAEA Technical Co-operation projects active in:

- **Tunisia** – Extraction of U and REE from phosphates (2012-14)
- **Egypt** – Extraction of U and REE from strong Phos acid and granites (2014-15)
- **Philippines** – Extraction of U and REE from Phos acid; Phosphogypsum utilization (2012-15)
- **Jordan** – Extraction of U from Phos acid (2014-15)
- **Preliminary studies are supported by laboratory and bench level tests.**



Sustainable outcome through integrated flow sheet

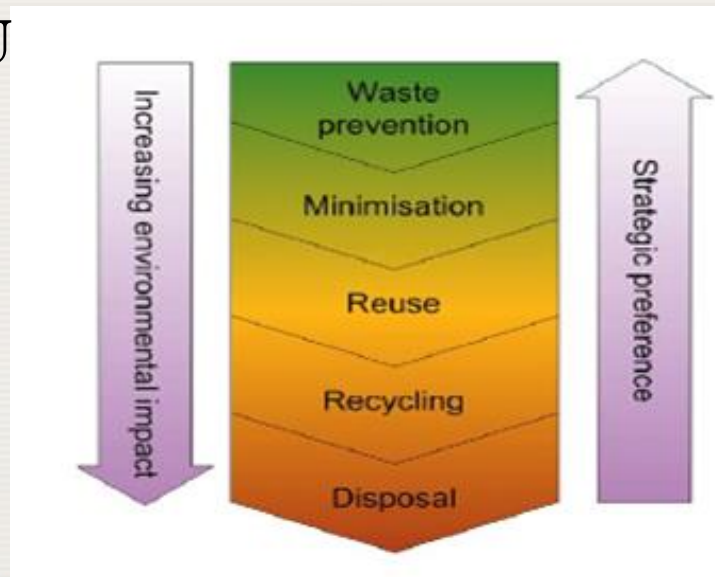


TBL 3 - Environmental
– Zero Waste
**RESTORING THE
EQUILIBRIUM,
OR WASTE TO WEALTH**

Rationale – Rethinking “Waste”

- Projects for managing any waste in isolation from the processes that generate them are running against the **policy objectives of the waste hierarchy** (e.g., EU Waste Framework Directive, 1975; US Non-Hazardous Waste Management Hierarchy)
 - disposal as the last, and least desirable of the management options
 - projects showing signs of “**not performing well when undertaken purely as waste management tasks**”

EU



US



Familiar cases

- Fly-ash in construction
- Capturing flared gas
- Metal recycling and reuse
- Vitamin E...

Challenges

- **Mine tailings**
 - U process tailings
 - Gold and other process tailings
 - Individual mines producing > 200,000 tonnes of tailings per day.
- **Mine wastes** – [often low grade ores]
- **Phosphogypsum piles** – Current production sent to stacks 160 million t/year; to increase to 200-250 million t/year in a decade or two. 3-4 billion t stacked worldwide (2006).
- **Coal ash piles**
- Residues...
- **Competitive land use**
- **Competitive water use**

Reference CX examples U and P

- Olympic Dam (Australia): U, Cu, Au, Ag ...
- Legacy tailings “reprocessing” projects
 - Past experience in Kaltails project, Kalgoorlie, Western Australia (695 000 oz gold recovered)
 - Possible gold and uranium recovery from tailings, Tajikistan
 - Uranium tailings – 2009 "Involvement of the private sector in the legacy tailings remediation , Central Asia: Reprocessing of tailings for recovery of valuable constituents," Kyrgyz Government.)
 - Las Lagunas project in the Dominican Republic (Ag-Au)
 - Silver-gold tailings project in Sonora, Mexico
 - Clayton Silver Mine, Idaho, USA
 - Today 70% of tailings investigated for “re-processing”
 - Uranium recovery from coal ash – USA, China,
- Phosphogypsum utilization (20 million tonnes/yr, 2014 – 0 use 2008)
 - Direct use in agriculture, roads, building materials
 - Value-added products with REE, S recovery; new products eg ammonium sulphate
- Innovative business models
 - New CX style flow sheets such as found in Brazil (Santa Quitéria jv)
 - China (Wengfu business model)

“Waste” approach – lessons learned

- Waste an “orphan” issue
- Breaches the intergenerational contract (incompatible with sustainable development)
- Unattended legacy spots
- Costly remediation projects such as Wismuth (Germany), Superfund sites eg Rattlesnake Creek, (USA)
- Poor performance over time
- Undoing “reputational damage” – what is the cost to my business from NOT dealing with waste in a sustainable manner – Phosphate industry and Phosphogypsum (discharge or indefinite stacking)

Waste to Resource - possible solution

- Value addition to products, therefore increased returns.
- Value addition to land use.
- Application of the waste hierarchy - reuse and recycling.
- **“Re-adoption” of residues** by parent industries - not left in the orphan “waste management” state
- Full life-cycle management.

Methodology (CX)

- Derived in theoretical terms from comprehensive extraction
- Energy basin management models
- Recover (secondary) resources and reuse
- Develop new products from recycling tailings or PG.
- Not a simple research activity - but as a well defined assessment of extraction projects

Quantities associated with known and potential resources

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Accurate and transparent management of essential materials

Recommendations (1)

Task Force: Sustainability Indicators in Resource Classification and Management for UNFC

1. Establish Multidisciplinary EGRC Task Force on **Sustainability Indicators in Resource Classification and Management for UNFC**

2. ToR to include, but not restricted to:

- Gap analysis – identification of additional specifications for project sustainability indicators/ desired outcomes
- Development of generic specifications for definition of identified sustainability KPIs for resource whole life-cycle management
- Development of commodity-specific specification for sustainability, including residues and tailings
- Development of Guidelines for Project Tools and Good Practices
 - sustainability diagnostics/ checklist
 - application of the Sustainable Development Evaluation Scorecard
 - KPIs
 - TBL measures of return including stakeholder engagement and social licence

Recommendations (2)

3. Proof of concept from sustainability study, life-cycle management U and Th resources and associated minerals, including residues and waste – with case studies, where known
4. Conduct associated “table-top” PFS, focused on the whole energy basin model; adopt “zero waste” and “energy neutral/energy positive” constraints

Thank You

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