Comprehensive Extraction

Harikrishnan ‘Hari’ Tulsidas

Division of Nuclear Fuel Cycle & Waste Technology, IAEA

Vice-Chairman, Expert Group on Resource Classification (EGRC)

Member, Technical Advisory Group, UNFC

IAEA

International Atomic Energy Agency

Comprehensive extraction

- 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
- **Disturb the ground once… extract everything of value in one pass**
- 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
- 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

IAEA

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		

IAEA

Conventional U resources - 7 096 600 tU (The ‘Red Book’ 2011)

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 to 110		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

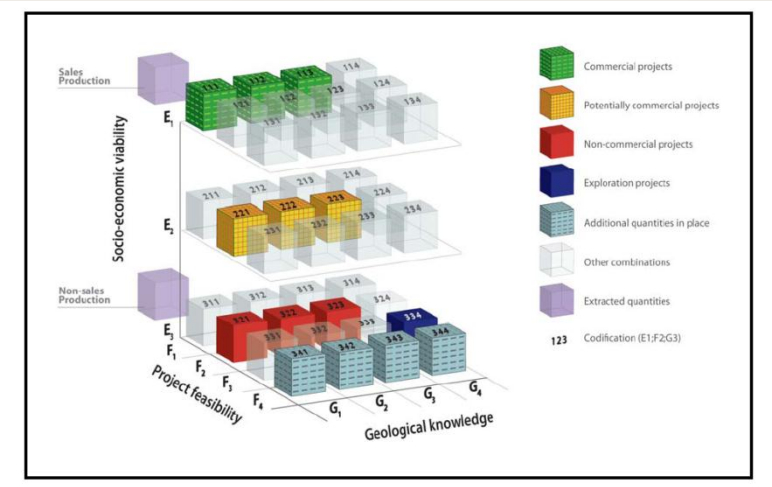
Phosphate rock source	Ln_2O_3 (%)
Kola, Russia	0.8-1.0
Florida, USA	0.06-0.29
Algeria	0.13-0.18
Morocco	0.14-0.16
Tunisia	0.14
Quebec, Canada	0.18
Ontario, Canada	1.59% (La_2O_3+Ce_2O_3)
Northern China	1.5 – 6.41 (Total R_2O_3)

- **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.**

IAEA

Operationalizing sustainable development

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



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

IAEA

Assessing comprehensive extraction

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 raffinite and slags

Available in tailings and clays

Not Commercial for current extraction

Potential for Commercial extraction

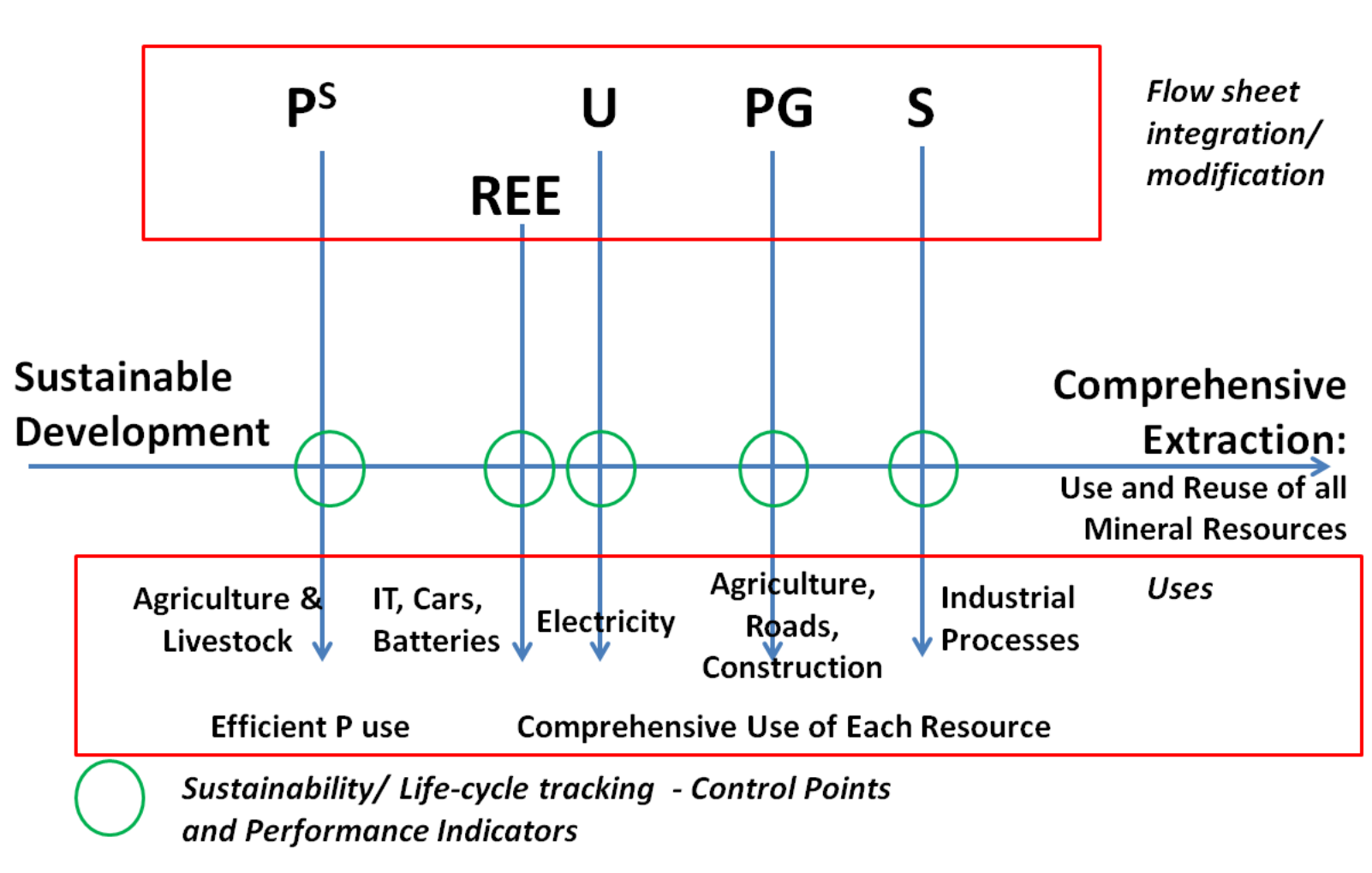
Commercially Extracted quantities

Dissipated in products, wastes, environment

Accurate and transparent management of essential materials

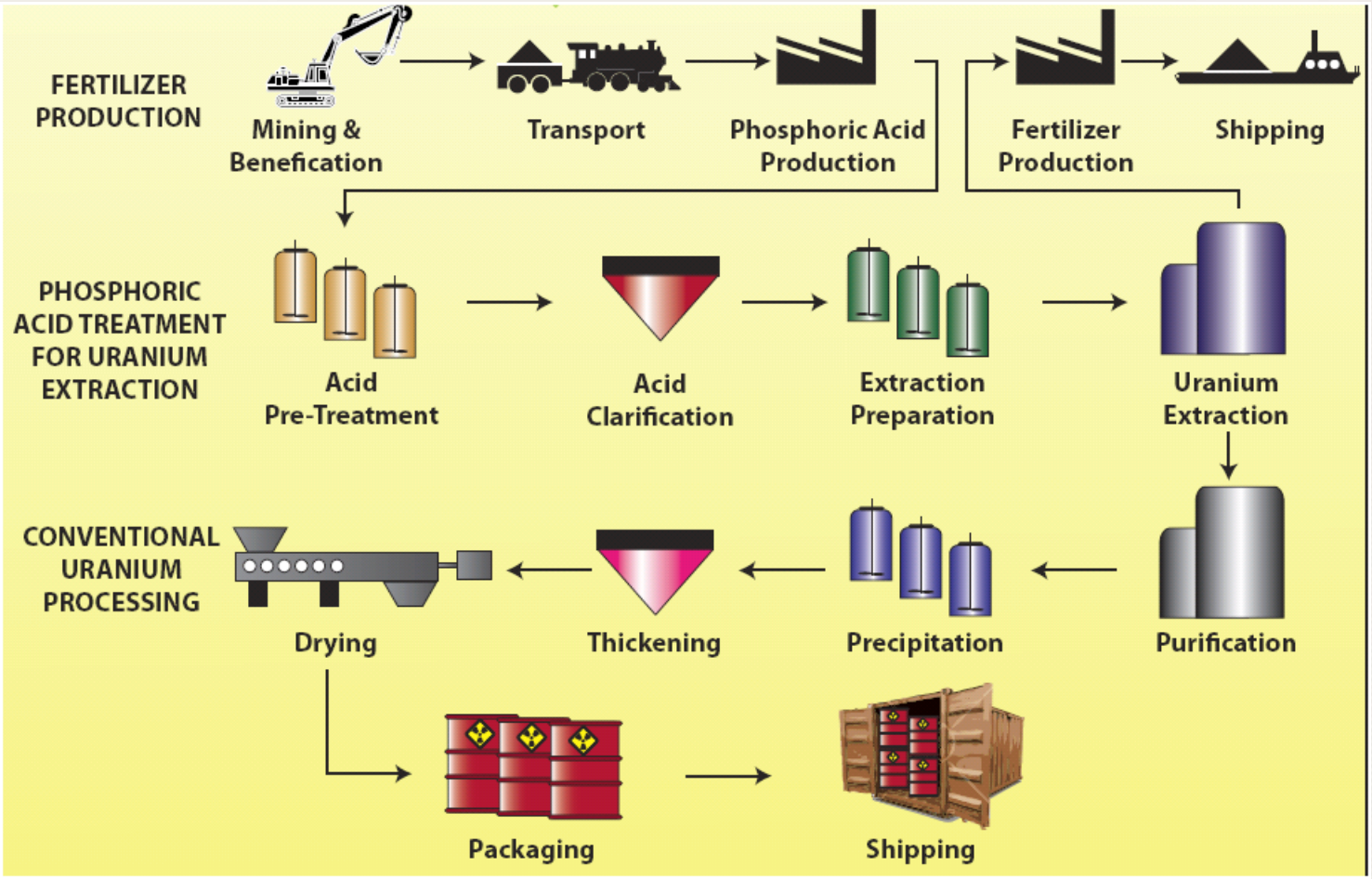
IAEA

Sustainable outcome through integrated flow sheet



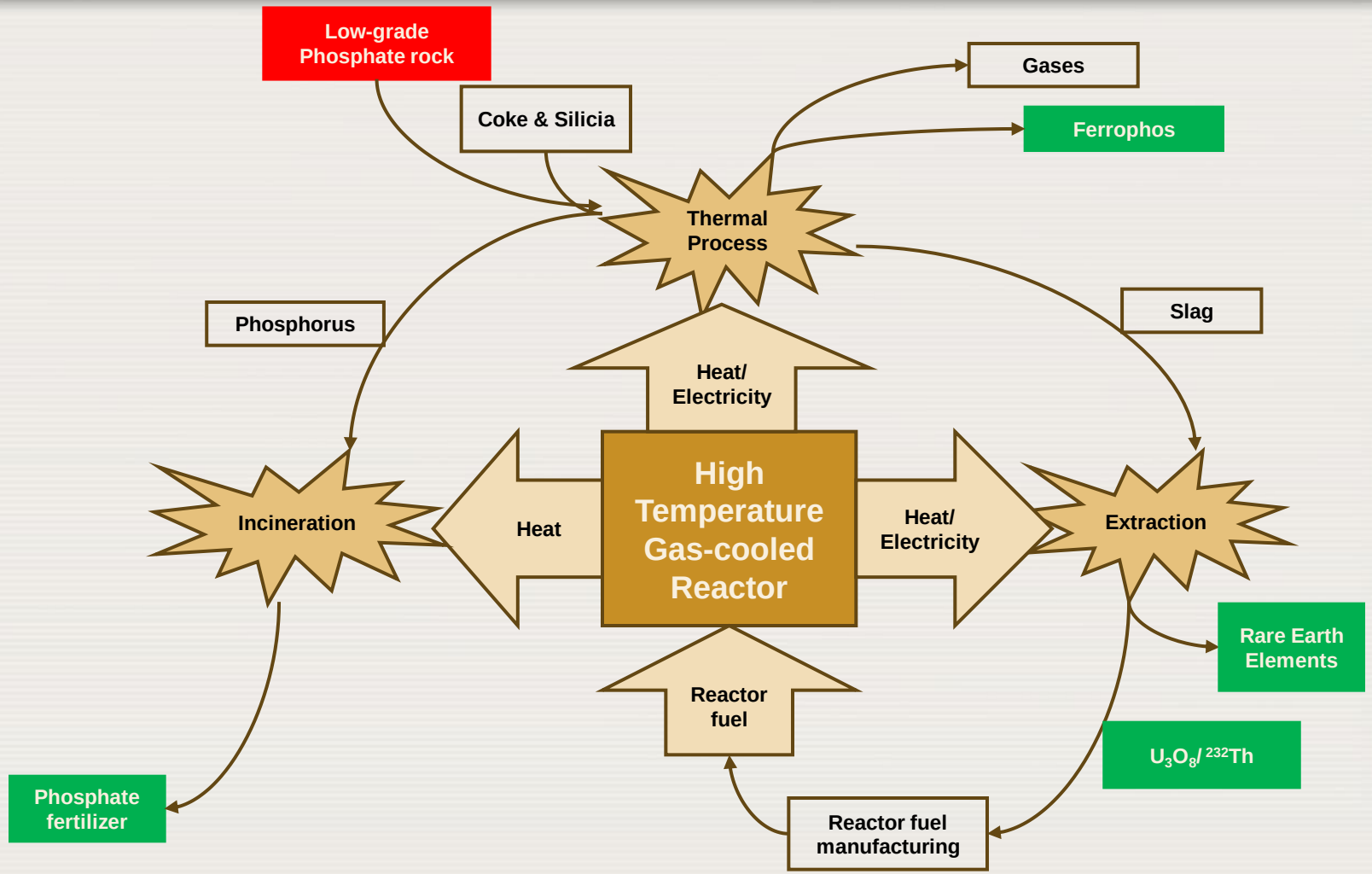
IAEA

Solvent extraction for Uranium



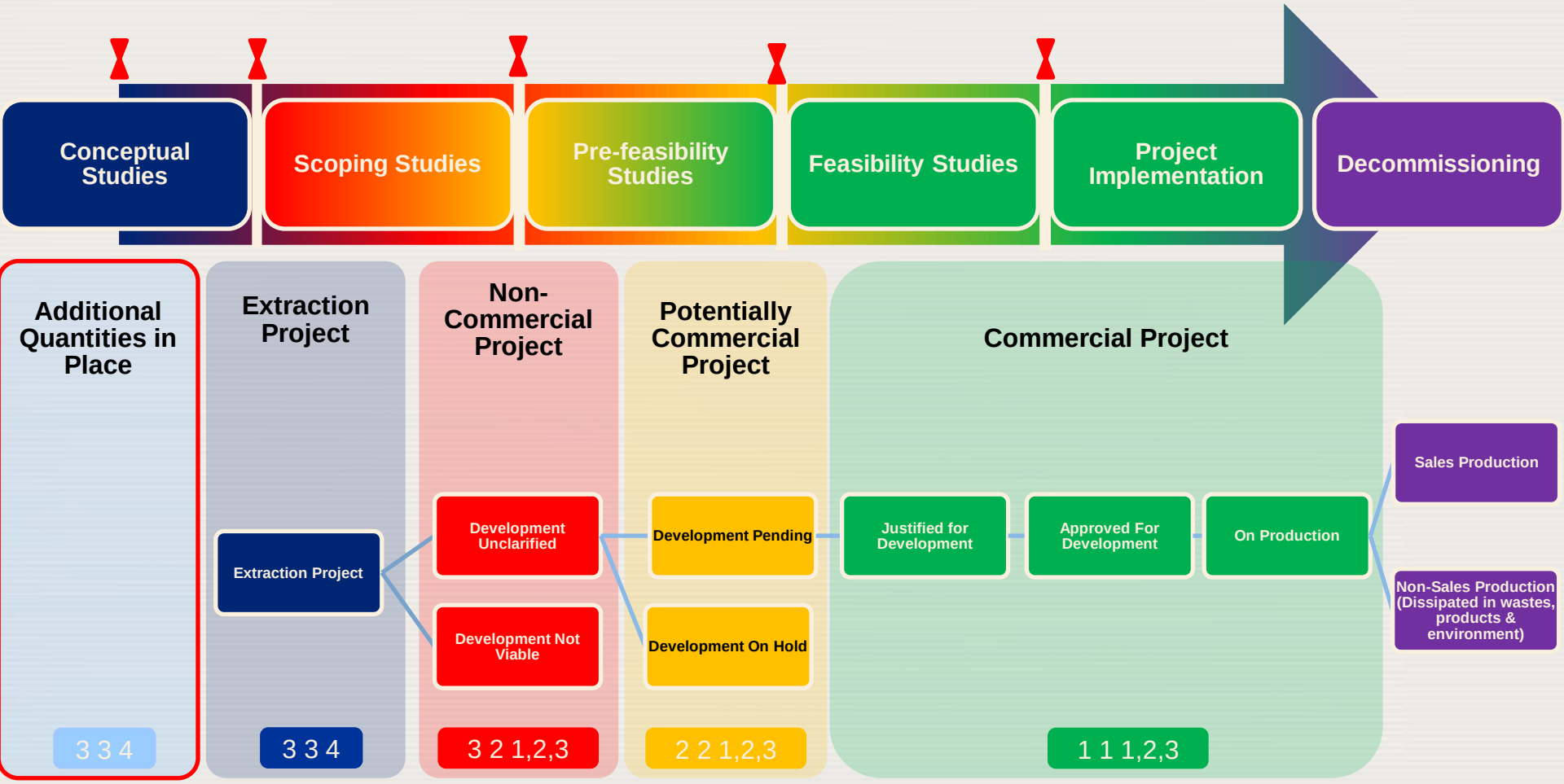
IAEA

Energy Neutral Phosphate Fertilizer Production



IAEA

Comprehensive extraction lifecycle



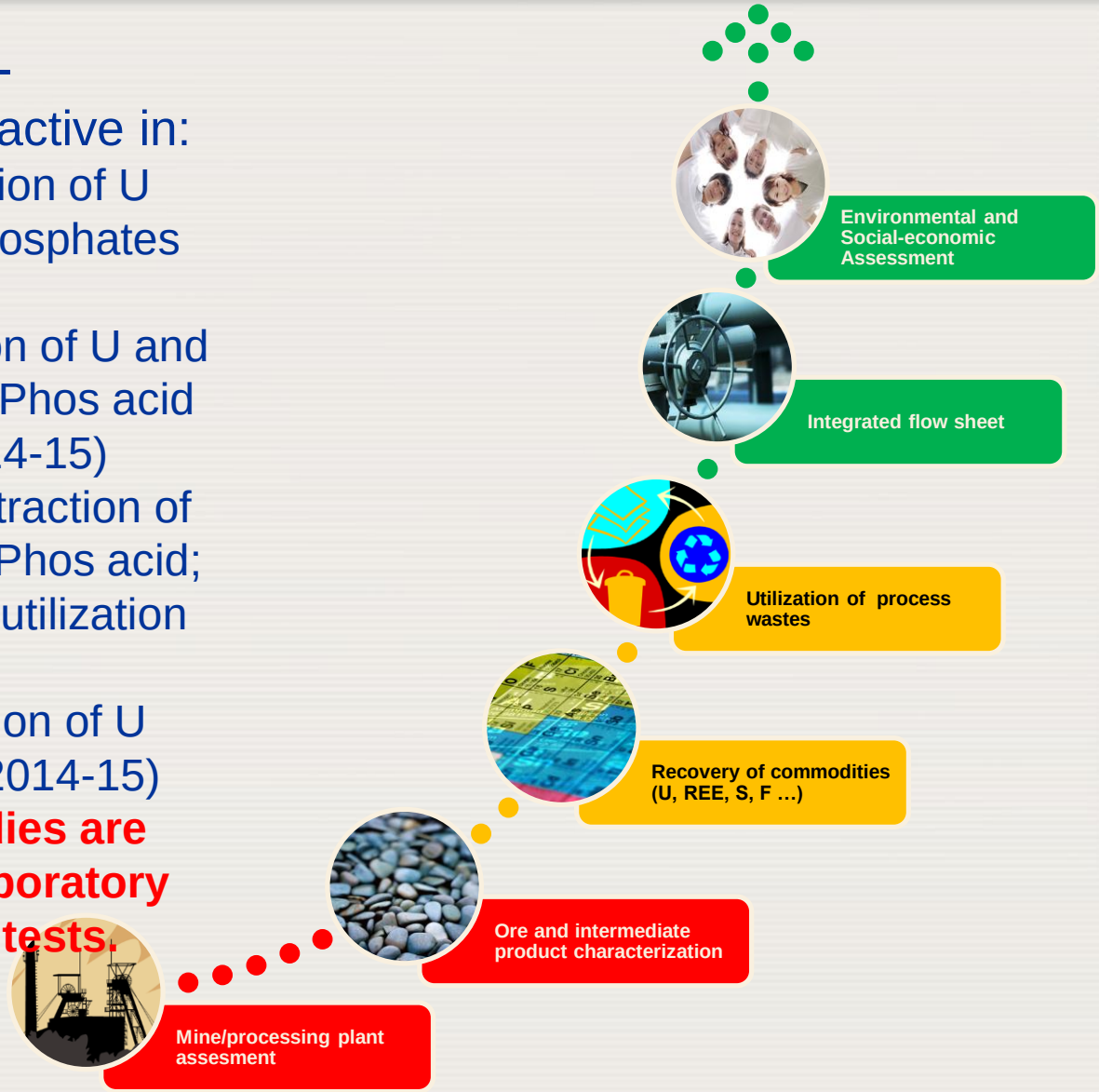
Accurate and transparent management of essential materials throughout the lifecycle

IAEA

Conceptual 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.**



IAEA

Thank you

Harikrishnan TULSIDAS | Nuclear Technology Specialist |
Section of Nuclear Fuel Cycle and Materials | Division of Nuclear Fuel Cycle and Waste Technology | Department Nuclear Energy |
International Atomic Energy Agency | Vienna International Centre, PO Box 100, 1400 Vienna, Austria |
Email: **T.Harikrishnan@iaea.org** | T: (+43-1) 2600-22758 | M: (+43) 664-736-11790 | F: (+43-1) 2600-7 |
Follow us on **www.iaea.org**

IAEA