

REINHOLD ENVIRONMENTAL Ltd.



**2017 APC & Wastewater Round Table
& Expo Presentation**

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An Economic Model Approach to FGD Wastewater Treatment

Integrated ELG Solutions

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July 17, 2017



Agenda

Amec Foster Wheeler & ELG

Complexity of ELG Compliance

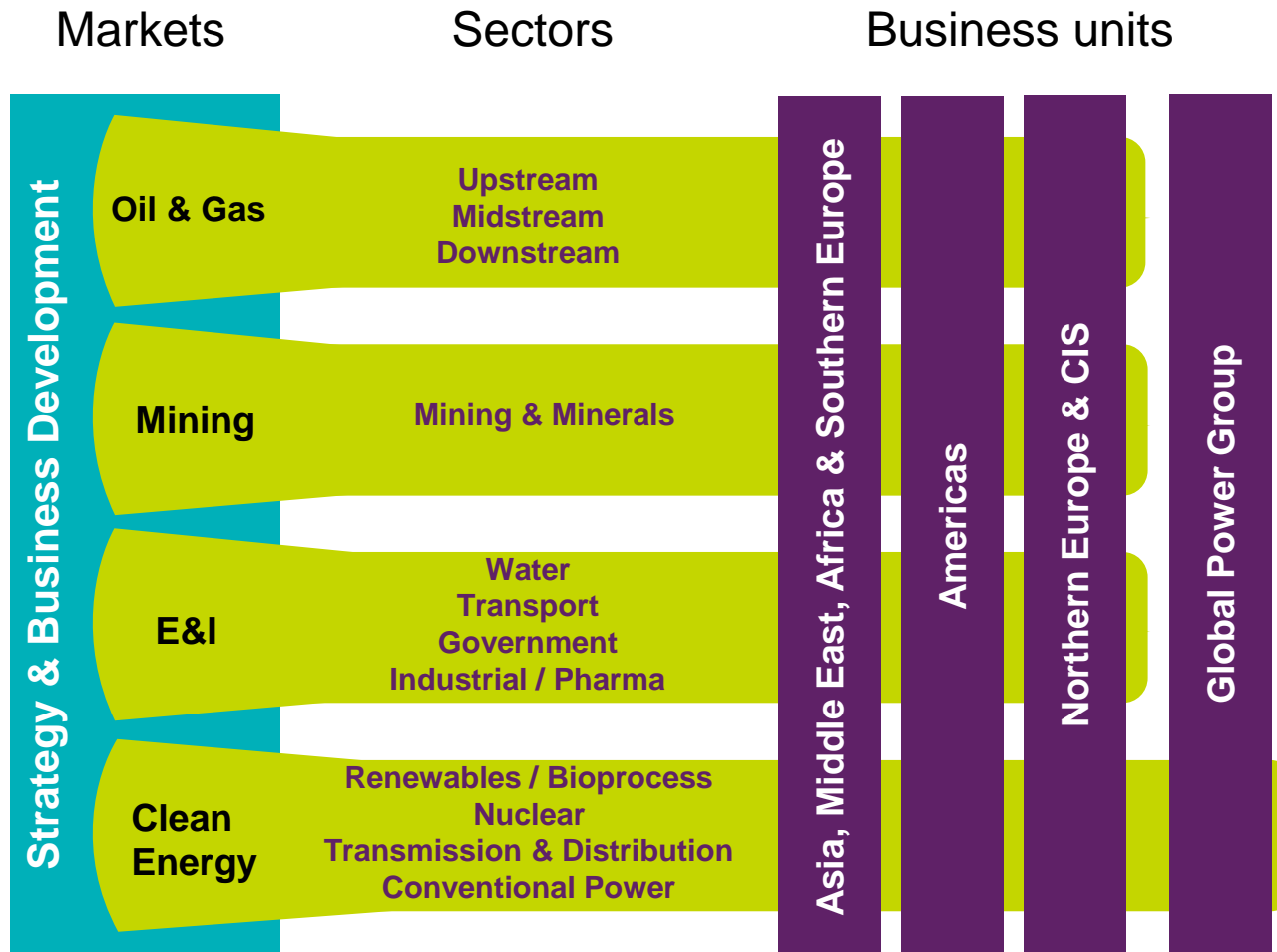
Development of Integrated Solutions

Overview of Amec Foster Wheeler's Model

Case Study Examples

Amec Foster Wheeler

Shared resources and expertise from other market sectors



Amec Foster Wheeler - ELG Experience

Conducted numerous ELG Engineering Studies over past few years

Full range of ELG Capabilities & Subject Experts

EPC

Wet to Dry Conversions

CCR, Geotechnical, Environmental

Wastewater Treatment

Wet Scrubbers & Spray Dryers

Mining Solutions & Paste

Expertise rooted in extensive WWT experience in Mining & Metals

ELG solutions to likely mimic mining

Complexity of Selecting Optimum ELG Compliance Options



Discharge requirements are stringent (selenium and nitrogen)

Water quality and flow variations

Treatment technology choices for selenium are limited

Compliance schedule and incentives

Site specific conditions and constraints

- Type of coal

- Need for fuel flexibility

- Scrubber design and limitations

- Capacity factor

- Current by-product disposition (gypsum, fly ash)

- Landfill space and capacity

Pathways to Compliance

EPA's BAT Technology Basis:

- Phys-Chem + Biological Treatment

Compliance Schedule
Based on NPDES
Renewal

NPDES
Outfall

Voluntary Incentives Program:

- Reverse Osmosis
- Mechanical Evaporation
- Crystallizers
- Spray Dryers
- Solids Fixation

Extended Compliance
Date Possible

Zero Liquid
Discharge

Biological Treatment Considerations

Biological Systems Prefer:

- Steady state flow conditions

- Consistent water quality (temp, chemistry)

- Reduced levels of TDS (slows down rate), chlorides, bromides

WFGD Scrubber Operating Strategy:

- Increase scrubber blowdown to “dilute” constituents and deliver constant flow with low TDS concentrations

Constraints:

- Shutdown/start-up lag time: minimum 2 weeks

- Scrubber chemistry changes (coal, limestone, makeup water)

- Existing capacity of physical chemical WWT

- Cannot handle oxidants (toxic)

ZLD Technology Options

Volume Reduction



Reverse Osmosis



Mech Evaporation

Conversion to Dry Solids



Crystallizer



Spray Dryer

Liquid or Solids Fixation



Paste Technology



Solidification of Brine

ZLD Technology Pretreatment Options

Desaturation & TSS Removal



Phys-Chem



Pond

Chemical Precipitation



Lime – Soda Softening



Barium Precipitation

Media



Ion Exchange

Developing Integrated Solutions for ELG Compliance

What are Integrated Solutions

Site specific water treatment systems that are constructed by incorporating a variety of treatment technologies

Why Consider Integrated Solutions for ELG

Combining technologies often results in multiple benefits that can not be achieved as stand-alone technologies:

- Lower energy consumption

- Higher Water Recovery

- Lower waste production

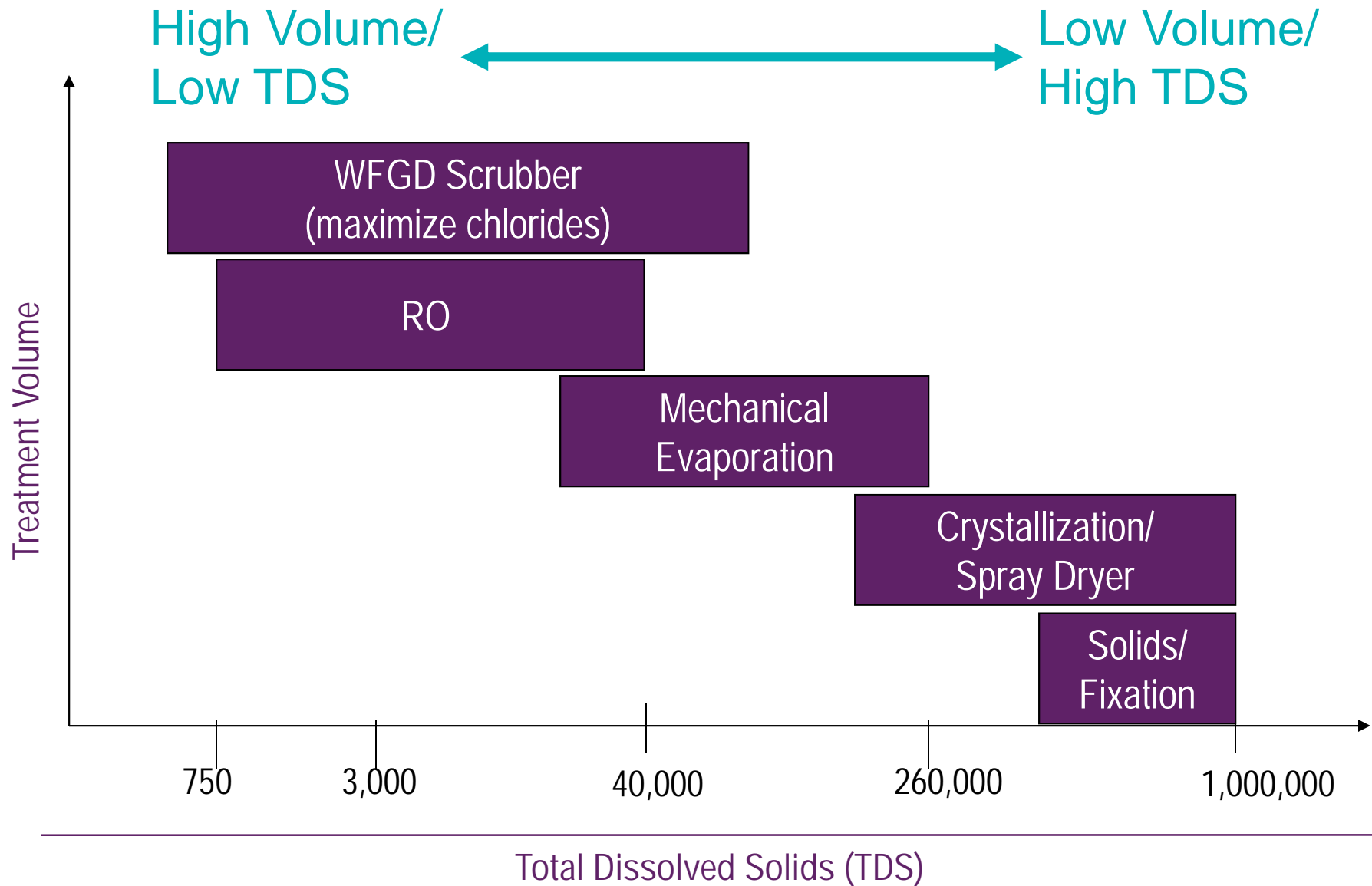
- Increases potential to produce saleable byproducts

Lower Cost

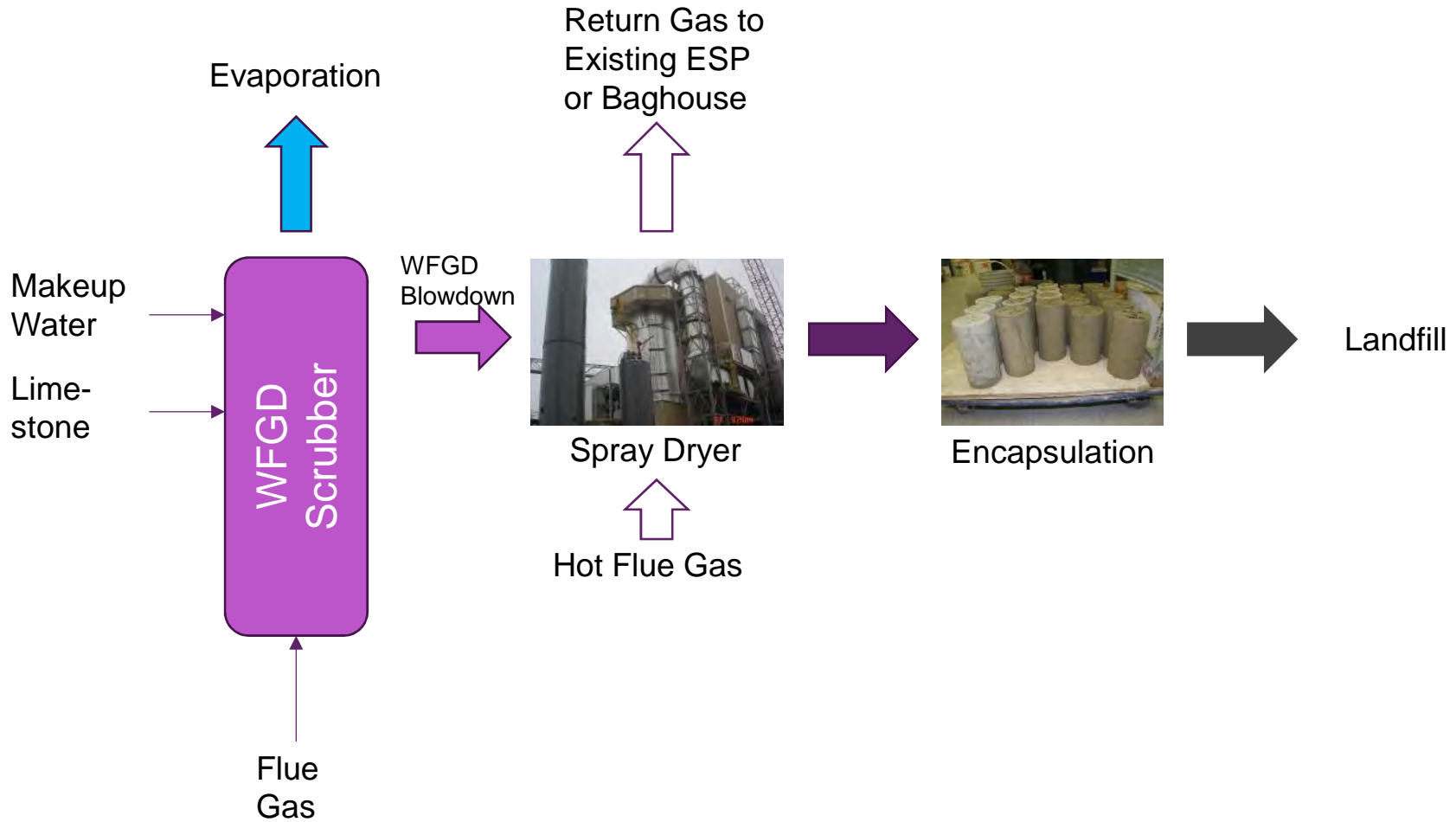
- O&M costs

- Capital costs (more suppliers, smaller systems, etc.)

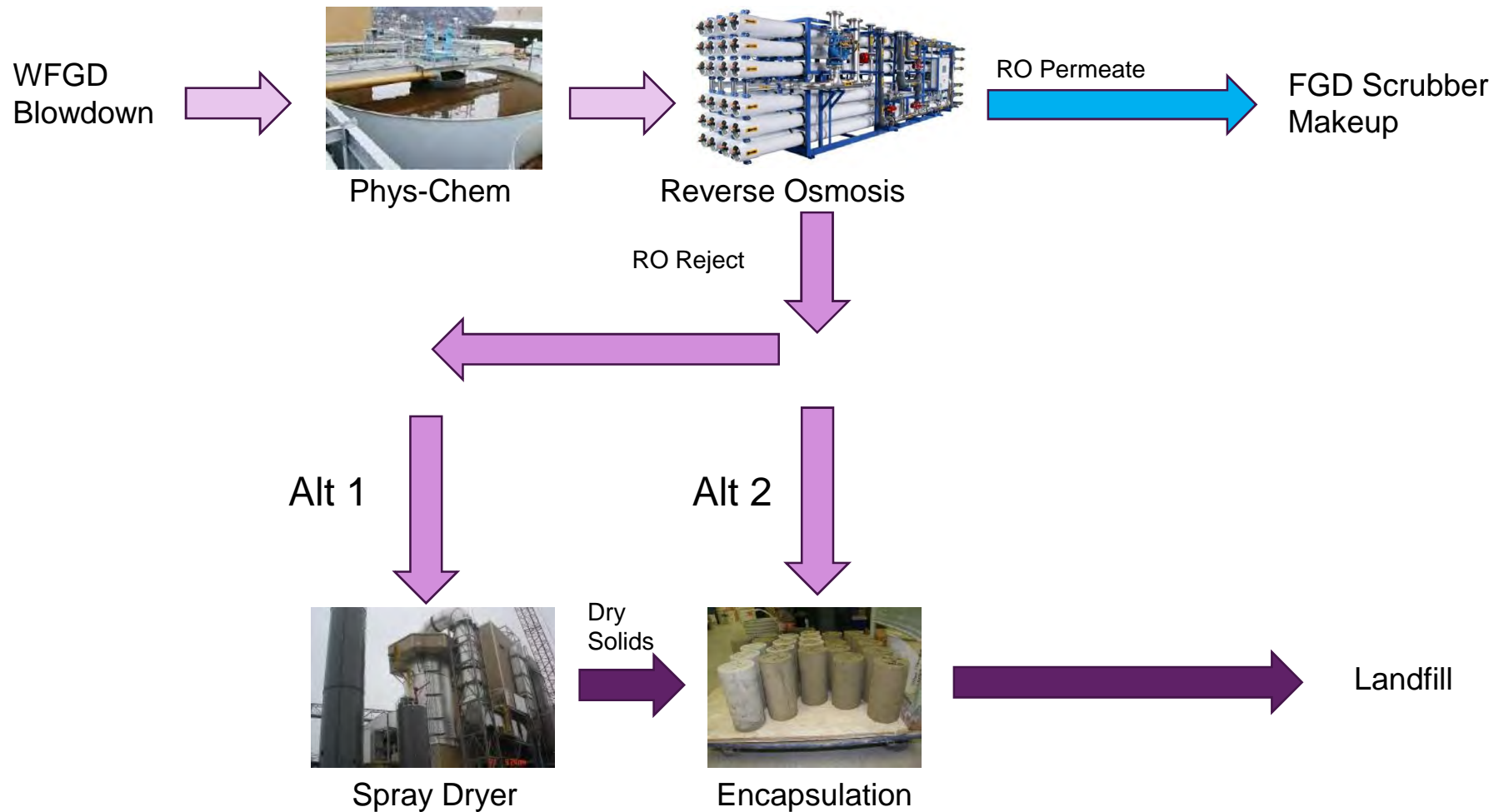
Optimization of ZLD Technologies



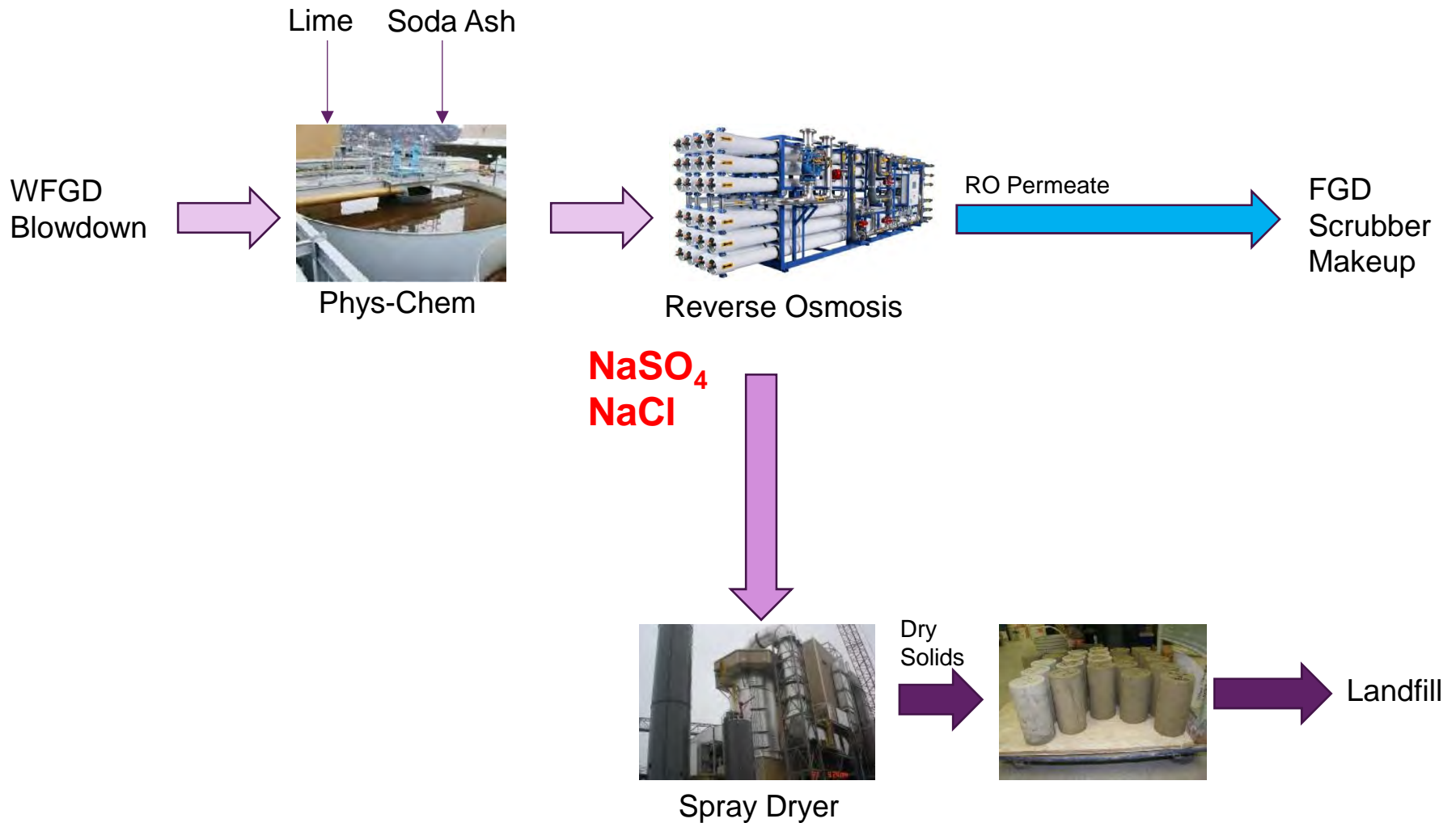
Technology Combinations: Example 1: Low Volume/High TDS Blowdown



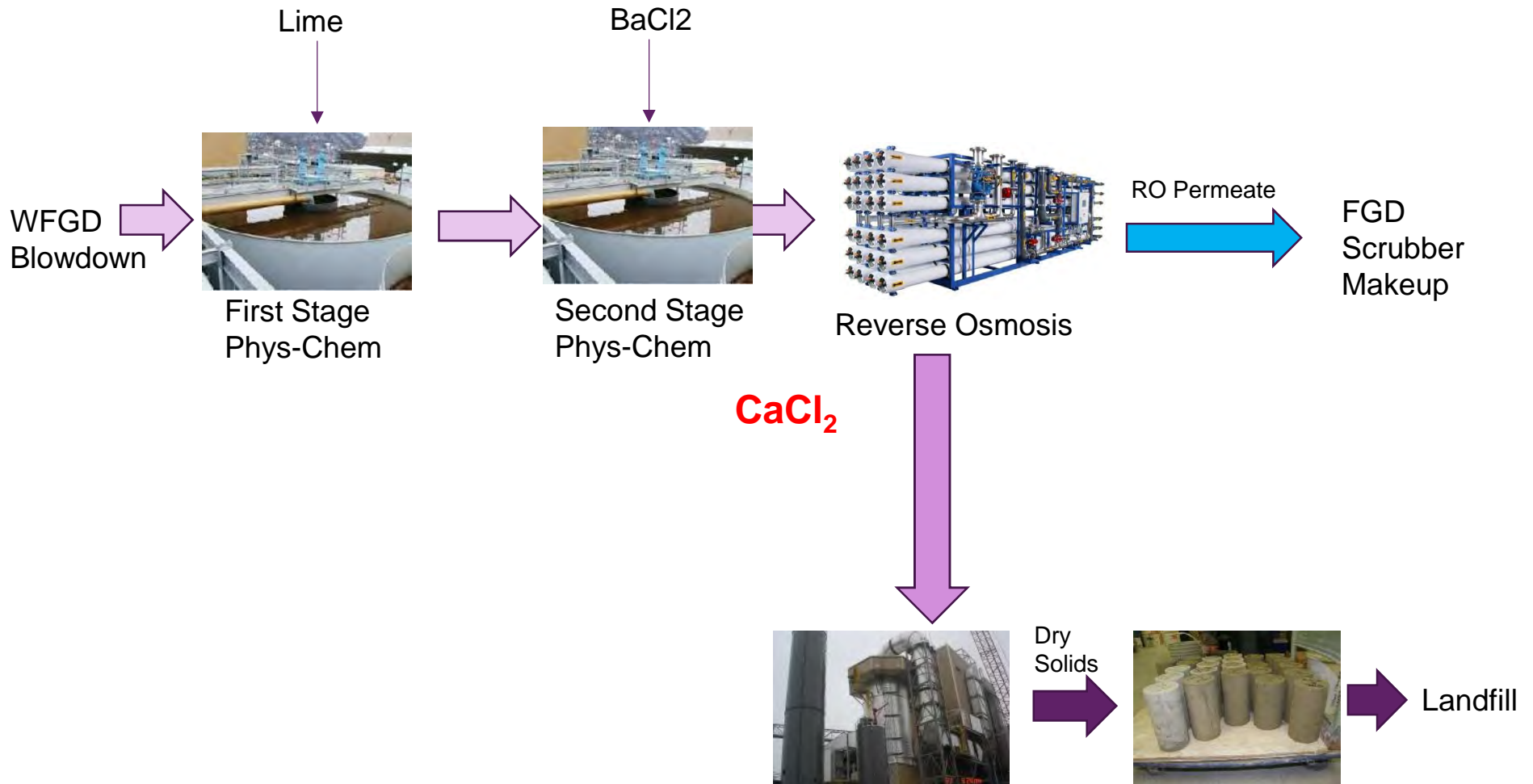
Technology Combinations: Example 2: High Volume/Low TDS Blowdown



Example 3: RO with Lime/Soda Softening Pretreatment (low calcium, high sulfate)



Example 4: RO with Barium Pretreatment (high calcium, low sulfate)



Amec Foster Wheeler Economic Model Overview



Helps begin iterative and customized approach to final ELG solution

Model was developed and optimized over feasibility studies

Process and economical Model

Excel based and simple to use

Fast, accurate, and comprehensive

All key ELG technologies included in the model

Easily customized for novel technologies

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Objectives of Model

Greatly accelerates the time to evaluate and “short list” treatment technologies for pilot testing and optimization

Models water chemistry throughout entire process, including recycle streams

Allows “what-if” analysis of process variables





Inputs & Outputs & Variables

Inputs: Chemistry & Flow

Output: Costs (Capital, O&M, NPV)

Basis of Design – Flow & Water Quality

Parameter	Units	Scenario #1	Scenario #2	Scenario #3	Scenario #4	ELG Limit Monthly Ave
Flow Rate	gpm	550	350	250	400	
pH		6.8	5.8	5.8	40 to 55	5.8
Temperature	°C	2 to 32	262	10	13	161
COD	mg/L	29,643	41,730	56,004	22,448	13
TOC	%	2.7 to 8.1	22,000	2.7 to 8.1	2.7 to 8.1	11,322
TDS	mg/L	8,664	10,215	30,000	5,265	5,265
TSS	mg/L	966	59	15	774	31
Cl ⁻	mg/L	41	11	0	8	4.4
Ca ²⁺	mg/L	86	0	0	0	0
Mg ²⁺	mg/L	1,252	0	0	0	0
Nitrate - N	mg/L	3,001	0	0	0	0
Nitrite - N	µg/L	1,000	0	0	0	0
Na ⁺	µg/L	4	0	0	0	0
SO ₄ ²⁻	µg/L	4.1	0	0	0	0
Aluminum	µg/L	0	0	0	0	0
Ammonia as N	µg/L	0	0	0	0	0
Antimony	µg/L	0	0	0	0	0
Barium	µg/L	0	0	0	0	0
Bismuth	µg/L	0	0	0	0	0
Boron	µg/L	0	0	0	0	0
Bromine	µg/L	0	0	0	0	0
Cadmium	µg/L	0	0	0	0	0
Chromium	µg/L	0	0	0	0	0
Copper	µg/L	0	0	0	0	0
Fluoride	µg/L	0	0	0	0	0
Lead	µg/L	0	0	0	0	0
Manganese	µg/L	0	0	0	0	0
Mercury	µg/L	0	0	0	0	0
Molybdenum	µg/L	0	0	0	0	0
Nickel	µg/L	0	0	0	0	0
Selenium	µg/L	0	0	0	0	0
Silver	µg/L	0	0	0	0	0
Sulfur	µg/L	0	0	0	0	0
Tantalum	µg/L	0	0	0	0	0
Tin	µg/L	0	0	0	0	0
Vanadium	µg/L	0	0	0	0	0
Zinc	µg/L	0	0	0	0	0

Cost Summary Option 4 - All Scenarios

Description	Scenario 1 (550)	Scenario 2 (350)	Scenario 3 (250)
Flow (gpm)			
Flow (m ³ /s)			
Capital	\$32.1	\$22.3	\$26.7
O&M	\$2.7	\$2.4	\$2.3
NPV	\$65.9	\$52.6	\$54.9
Flow (gpm)	\$40.0	\$41.2	\$2.3
Flow (m ³ /s)	4	\$69.4	

Variables: pH, Reagents, Recovery, etc.

Output: Process Data - mass balances, material calculations, re-use quantities, process stops

Case Study

Treatment of FGD Blowdown



- Source: FGD Blowdown
- Peak Flow: 400 gpm
- Avg Flow: 375 gpm
- Existing WTP: Phys-Chem
- Objective: ZLD

Parameter	Feed Water
Commons	
pH	5.8
Total Alkalinity	-
Nitrogen, Ammonia	0.8
Nitrogen, Nitrate	39.0
Silica	23.2
TOC	13.0
Anions	
Chloride	11,322
Fluoride	8
Nitrate	173
Sulfate	1,240
Cations	
Calcium	5,641
Magnesium	774
Sodium	51
Other	
TDS (180 Deg C)	19,272

Case Study

Alternative Solutions



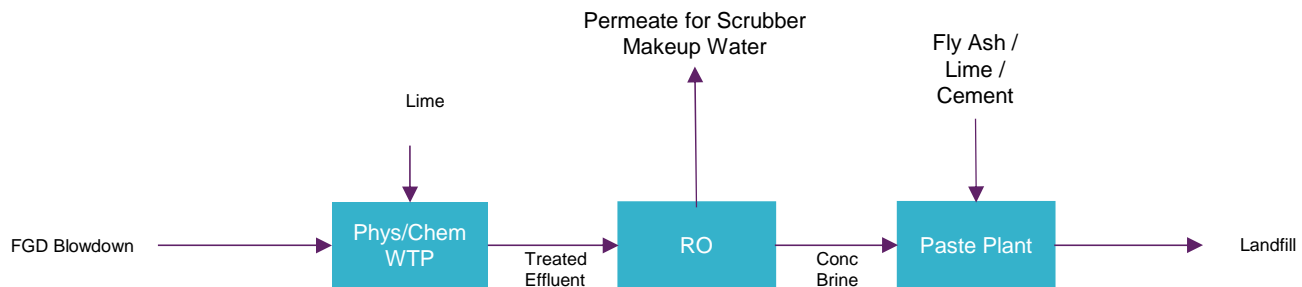
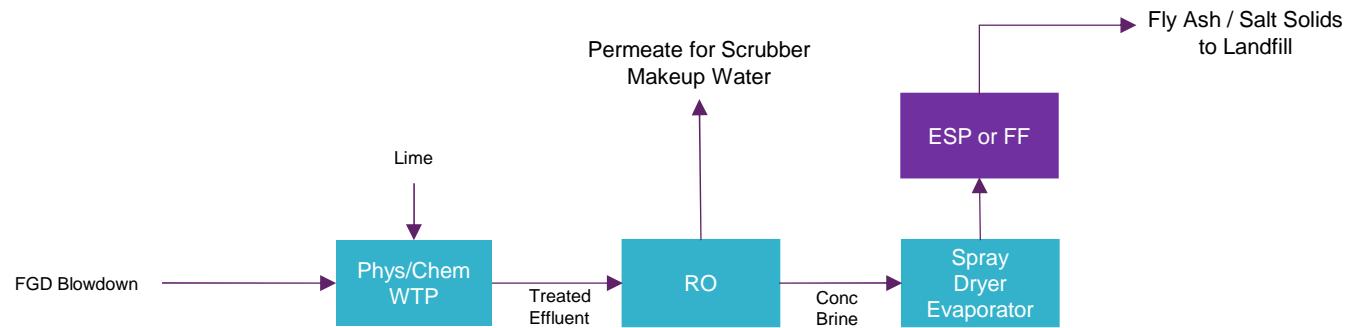
Option 1. RO + Spray Dryer or Paste

Option 2. Lime Soda Softening + RO + Spray Dryer or Paste

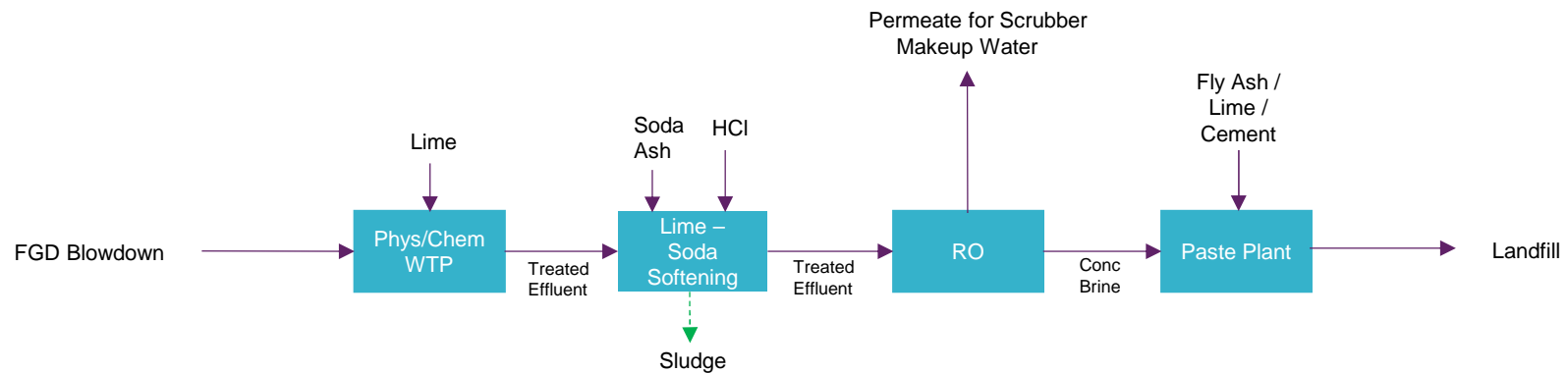
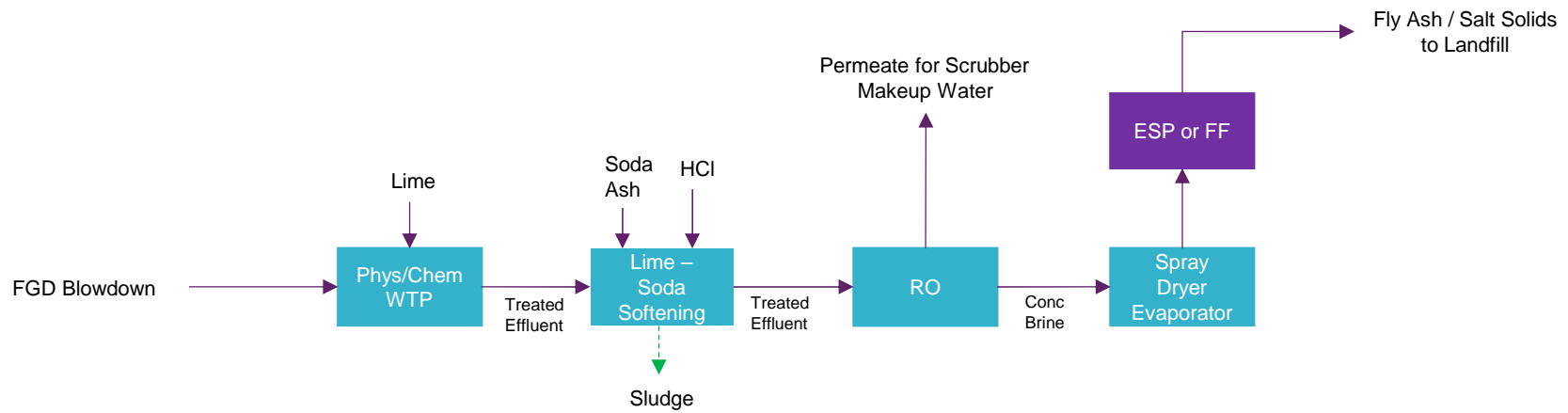
Option 3. Barium Precipitation + RO + Spray Dryer or Paste

Option 4. Mechanical Evaporation + Spray Dryer or Paste

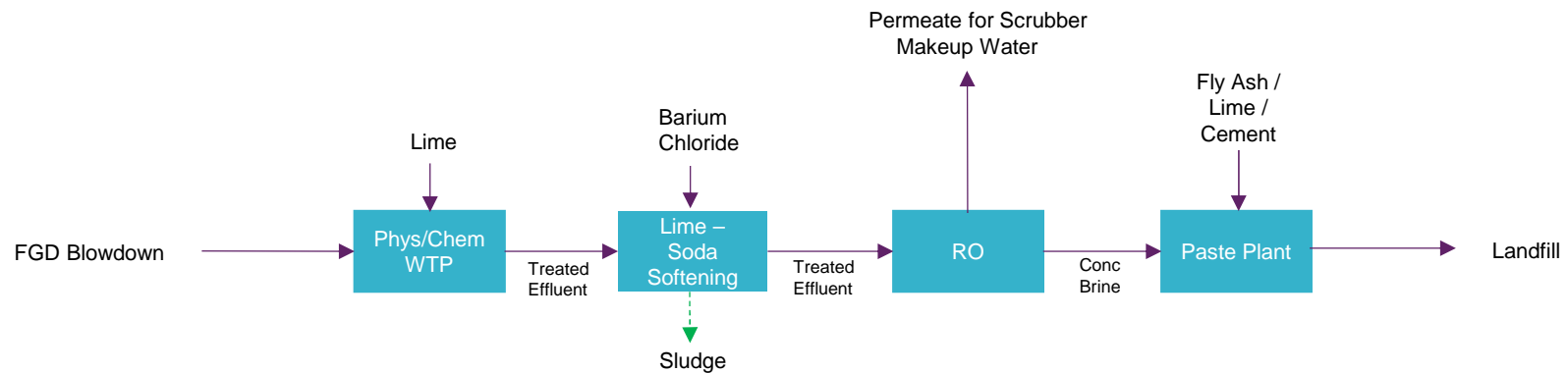
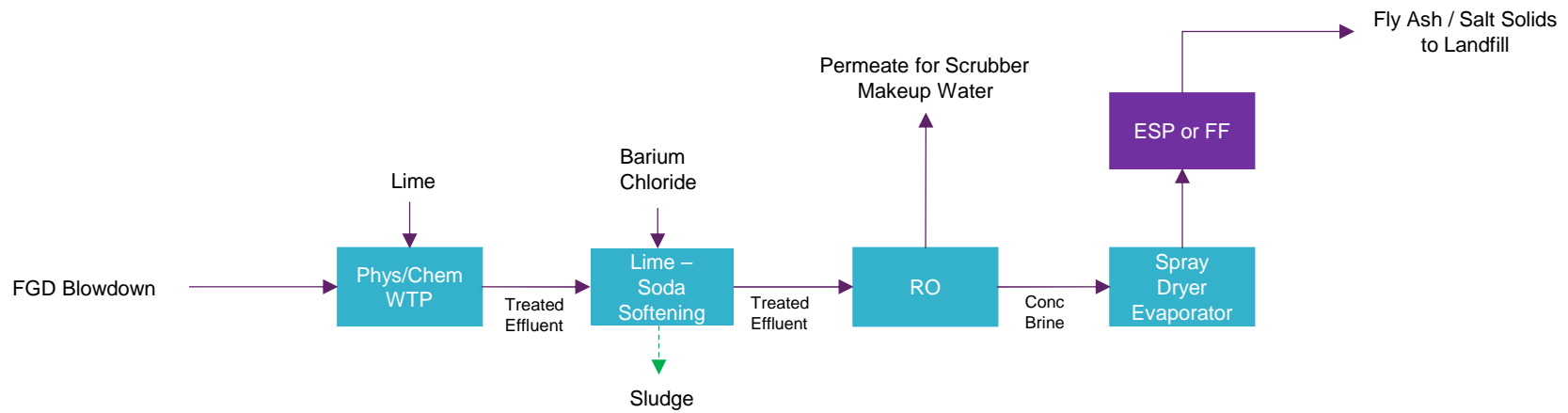
Option 1 RO + Spray Drying or Paste



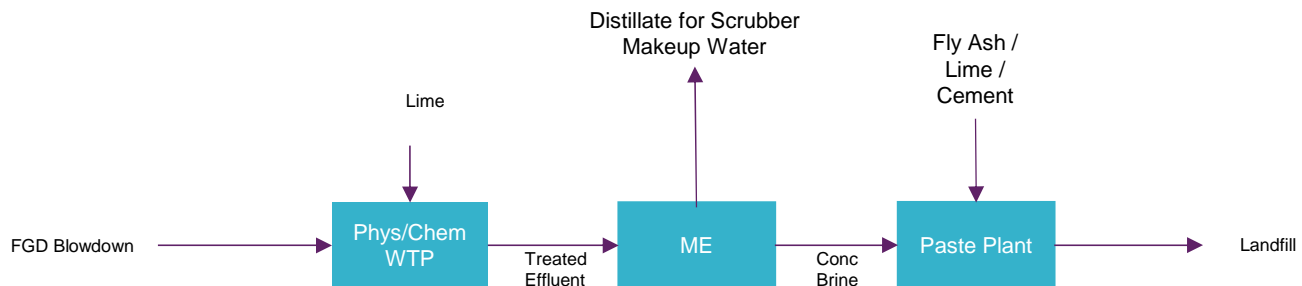
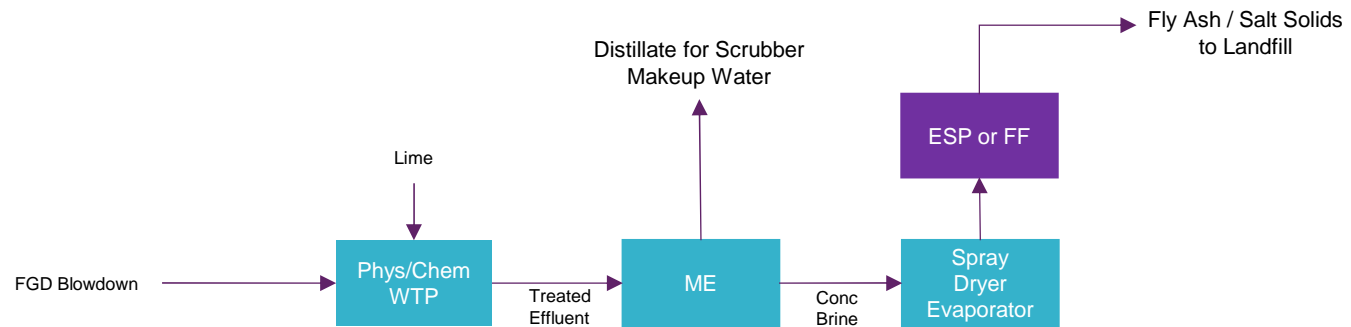
Option 2 LSS + RO + Spray Dryers or Paste



Option 3 BaP + RO + Spray Dryers or Paste



Option 4 Mechanical Evaporator + Spray Drying or Paste



Cost Development

Capital Cost Estimates

Factored Cost Estimate

Budgetary Equipment Costs from Previous Projects

Accuracy: -30%/+50%

O&M Cost Estimate

Labor

General Maintenance

Energy Cost Estimates

Reagents

Membrane Cleaning/Replacement

Waste Disposal

By-product Recovery Credits

NPV

Discount Rate: 5%

Duration: 20 years

Cost Comparison

	Option1 RO Only		Option 2 LSS + RO		Option 3 BaP + RO		Option 4 ME	
	Spray Dryer	Paste	Spray Dryer	Paste	Spray Dryer	Paste	Spray Dryer	Paste
Total Installed Costs	\$50.0	\$10.7	\$46.8	\$26.9	\$46.3	\$26.4	\$66.8	\$36.9
Total Annual Costs	\$3.2	\$20.8	\$4.1	\$13.5	\$6.9	\$16.2	\$2.3	\$9.3
NPV (5%, 20 yrs)	\$90.5	\$269.9	\$97.4	\$194.6	\$132.5	\$228.4	\$95.8	\$153.1

Cost in Millions \$

Summary

Integrated solutions that combine treatment technologies often results in multiple benefits that may not be achieved as stand-alone technologies

The use of a detailed material balance model can significantly shorten the time to evaluate a integrated solutions for ELG compliance

Objective apple-apple comparisons between solutions can be made with respect to both performance and cost

Results should be used to selecting technologies for further evaluation and pilot testing

Questions

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