Product Range and The Competitive Positioning Of Polyethylene Production Technologies

Polyolefins 2017 International Conference

Society of Plastics Engineers

Houston, February 28, 2017

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Agenda

- Competition in the polyethylene industry
- Market needs/Supplier offerings
- Capacity to produce
- Process selection: The proliferation of technologies
- Complexities of competition in PE markets
- A means to tackle this complexity
- Summary & status

Competition In Polyethylene Markets

Competition in a regional market can be represented as a matrix of demand by PE grade against supply from individual production lines

PE Demand by Grade / PE Supply by Plant	Resin Class Application Grade Density, kg/m3 Melt Flow, dg/min:	HDPE Blow Mld HIC 948-964 0.15-0.6	HDPE Blow Mld IBC 944-954 7F-10F	• • • • •	HDPE Injection Crates 954-964 8-10	• • • • •	LLDPE Film C6 918-920 0.5-1.2	• • • • •	Total Linear PE Supply Kilotons
	Capacity kta	Market Share Distribution							
Polyolefin Producer I									
Line A Gas Phase Fluid Bed	250	---	XXX	•	XX	•	---	•	225
Line B Gas Phase Fluid Bed	400	---	---	•	---	•	XXXX	•	365
Line C Slurry Loop Bimodal Cascade	235	XXXX	XX	•	---	•	---	•	220
• •	•	•	•		•		•		•
• •	•	•	•		•		•		•
• •	•	•	•		•		•		•
Polyolefin Producer N									
Line A Gas Phase Fluid Bed	350	XXXX	---	•	XX	•	X	•	315
Line B Solution - Cooled Loop Reactor Cascade	300	---	---	•	XXXX	•	XXXXX	•	280
Line C Slurry Loop Bimodal Cascade	450	---	XXX	•	XXX	•	---	•	440
Line D Slurry Stirred Tank - Hexane Diluent	200	X	XXXX	•	XX	•	---	•	180
	10,000								
Total Linear PE Demand, Kilotons		1,550	400	•	635	•	2,000	•	9,200

Market shares on a grade-by-grade basis reflect supplier strengths and market strategies

Reshuffling The Competitive Matrix

One supplier's gain in market share is another's loss, and the other's loss must be regained elsewhere

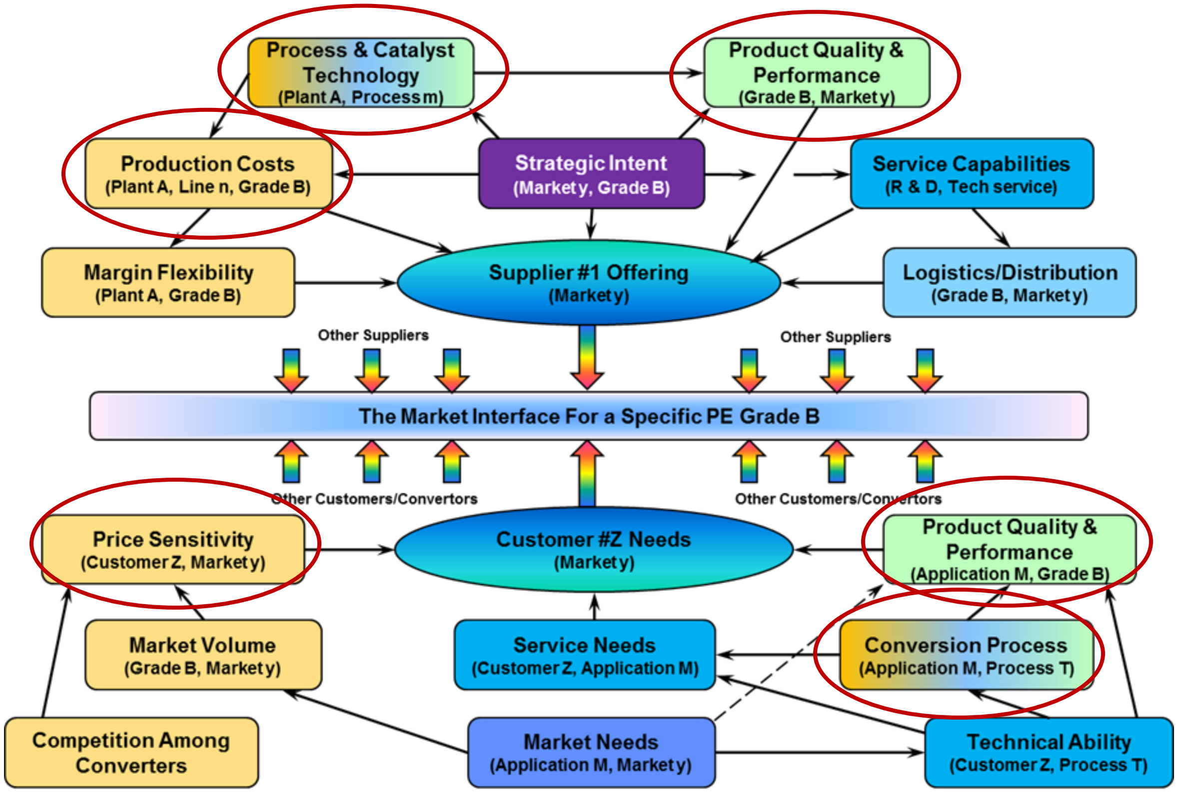
PE Demand by Grade / PE Supply by Plant	Resin Class / Application / Grade / Density, kg/m3 / Melt Flow, dg/min:	HDPE Blow Mld HIC 948-964 0.15-0.6	HDPE Blow Mld IBC 944-954 7F-10F	•	HDPE Injection Crates 954-964 8-10	•	LLDPE Film C6 918-920 0.5-1.2	•	Total Linear PE Supply Kilotons
	Capacity kta	Market Share Distribution							
Polyolefin Producer I									
Line A Gas Phase Fluid Bed	250	---	XXX	•	XX	•	---	•	225
Line B Gas Phase Fluid Bed	400	---	---	•	---	•	XXXX	•	365
Line C Slurry Loop Bimo	235	XXX	XX	•	---	•	---	•	220
• •	•	•	•		•		•		•
• •	•	•	•		•		•		•
• •	•	•	•		•		•		•
Polyolefin Producer N									
Line A Gas Phase Fluid Bed	350	XXX	---	•	XX	•	X	•	315
Line B Solution - Cooled Loop Reactor Cascade	300	---	---	•	XXXX	•	XXXXX	•	280
Line C Slurry Loop Bimodal Cascade	450	---	XXX	•	XXX	•	---	•	440
Line D Slurry Stirred Tank - Hexane Diluent	200	X	XXXX	•	XX	•	---	•	180
	10,000								
Total Linear PE Demand, Kilotons		1,550	400	•	635	•	2,000	•	9,200

New Plant

An enormous game of "Whack-A-Mole"!

The Matrix Reshuffle Is Not Random

Suppliers in a strong competitive position are closer to satisfying market needs

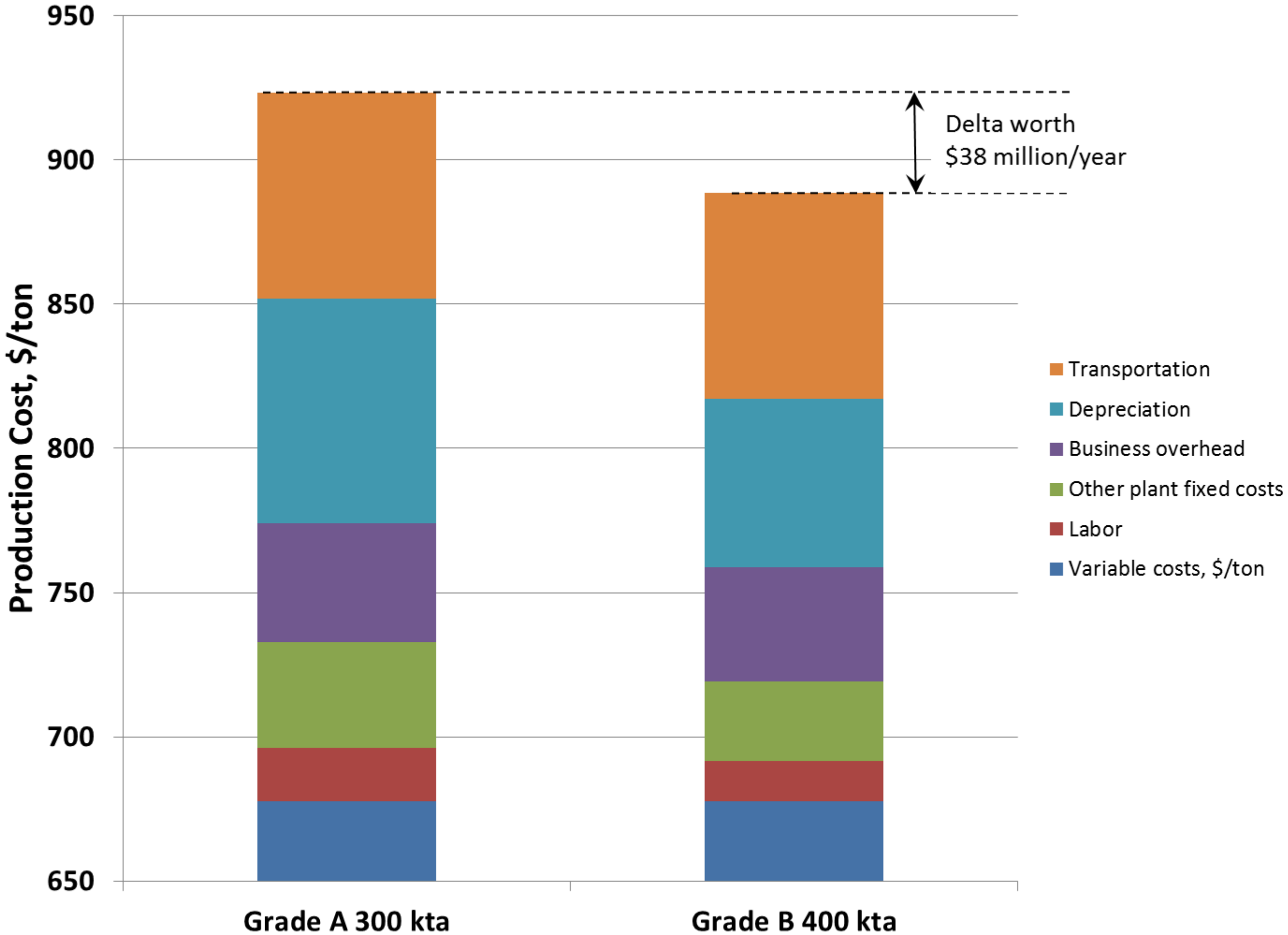


Stronger suppliers yield less; weaker suppliers must give way, but may be stronger in other markets/grades

Capacity To Produce

- The rate at which a plant can make PE usually varies from one grade to another:
  - Some grades are “slow” and incur relatively high fixed cost allocations per ton produced
  - Other grades are “fast” for which fixed cost contributions can be minimized.
    - For example, a plant may be designed to make a specific Grade A at a rate of, say, 300 kilotons per year or about 37 tons per hour
    - The same plant, without any modifications, may be able to make 400 kilotons per year of Grade B, or about 50 tons per hour.
  - What is the capacity of the plant?
    - If the production split between Grade A and Grade B is 50/50, the overall capacity to produce will be 350 kta.
    - If the production split is 30/70 the capacity is 370 kta
    - If the production split is 80/20 the capacity is 320 kta.
- Whatever the listed capacity of a plant, we need to know what product portfolio this capacity relates to.

Production Costs Depend On Production Rate



Suppliers need to know production costs of competitors on a grade-by-grade basis

Technology Selection For A New Plant

- Selection of a technology for a new plant needs to take into account the planned marketing strategy
  - No plant can satisfy all needs in a regional market
    - The product ranges of available technologies have limits and not all grades that the market needs can be made by one technology
    - There is a limit to the number of grades that one reaction line can produce on an ongoing basis
      - » Effectively 10-40 grades/line, depending on process
  - The optimal planned market strategy may be different for different process technologies
    - Each process has a set of grades for which it is most suited
- Each technology/strategy option must be evaluated for the optimal product portfolio
  - Costs and profitability of each option will depend on the weighted average cost of production for each and all grades in the portfolio, and the weighted average sales revenues for the portfolio

The Proliferation Of PE Technologies: LDPE

- LDPE was discovered 83 years ago and went into broad commercial production 63 years ago
- There are still only two process types available: autoclave & tubular reactor processes
- However, many companies have devised proprietary variations of these process so that there are now at least 34 variations in commercial operation
- New grades continue to be introduced on a regular basis

High Pressure Processes

Braskem	Braskem Atochem	High Pressure - Tubular Reactor
Braskem	Braskem Dual Autoclave	High Pressure - Autoclave Reactor Cascade
Dow	Dow	High Pressure - Autoclave Reactor
Dow	Dow	High Pressure - Autoclave/Tubular Cascade
Dow	Dow	High Pressure - Tubular Reactor
Dow	Dow	High Pressure - Tubular Reactor - Split Recycle
Dow	Dow Leuna/Polymir	High Pressure - Tubular Reactor
Dow	Dow Union Carbide	High Pressure - Tubular Reactor
Dow	Dow/Imhausen	High Pressure - Tubular Reactor - Multi Feed
DuPont	DuPont	High Pressure - Autoclave - Fully Backmixed
DuPont	DuPont	High Pressure - Autoclave Reactor Cascade
ExxonMobil	ExxonMobil	High Pressure - Autoclave Reactor
ExxonMobil	ExxonMobil	High Pressure - Tubular Reactor - Multi Feed
ExxonMobil	ExxonMobil/Mitsubishi	High Pressure - Autoclave Reactor - Metallocene
ExxonMobil	Retrofit	High Pressure - Autoclave Reactor - Tubular Tail
Japan PE	Mitsubishi	High Pressure - Tubular Reactor - Multi Feed
LyondellBasell	Equistar Tube	High Pressure - Tubular Reactor
LyondellBasell	Lupotech A	High Pressure - Autoclave Reactor
LyondellBasell	Lupotech T	High Pressure - Tubular Reactor - Front Feed
SABIC	SABTEC CTR	High Pressure - Tubular Reactor - Clean Tube
Simon Carves	ICI/Simon Carves	High Pressure - Autoclave Reactor
Sumitomo	Sumitomo	High Pressure - Autoclave Reactor
Sumitomo	Sumitomo	High Pressure - High Conversion Autoclave Cascade
Sumitomo	Sumitomo	High Pressure - Tubular Reactor
Versalis	Versalis ANIC	High Pressure - Tubular Reactor
Versalis	Versalis CdF	High Pressure - Autoclave Reactor
Versalis	Versalis CdF	High Pressure - Autoclave Reactor - Ziegler
Various/Proprietary	Arkema Atochem	High Pressure - Tubular Reactor
Various/Proprietary	Atochem	High Pressure - Tubular Reactor
Various/Proprietary	Borealis Union Carbide	High Pressure - Tubular Reactor
Various/Proprietary	CP Chem Gulf	High Pressure - Autoclave Reactor
Various/Proprietary	Imhausen	High Pressure - Tubular Reactor - Multi Feed
Various/Proprietary	Polymir	High Pressure - Tubular Reactor
Various/Proprietary	Uhde Ruhrchemie	High Pressure - Tubular Reactor

The Proliferation Of Technologies: Gas Phase

Gas Phase Processes

Borealis	Borstar	Supercritical Slurry/Gas Phase Fluid Bed	Bimodal
	Borstar 2G	Supercritical Slurry/Gas Phase Fluid Bed	Multimodal
	Borstar 3G	Supercritical Slurry/Gas Phase Fluid Bed	Multimodal
Ineos Technologies	Innovene G	Gas Phase - Fluid Bed	Dry
	Innovene G EHP	Gas Phase - Fluid Bed	Supercondensed
LyondellBasell	Hyperzone	Gas Phase - Fluid Bed/MZCR	Multimodal
	Spherilene C	Gas Phase - Fluid Bed	Bimodal
	Spherilene S/Lupotech G	Gas Phase - Fluid Bed	Dry/Condensed
Mitsui	Evolue	Gas Phase - Fluid Bed	Bimodal
Univation	Unipol	Gas Phase - Fluid Bed	Dry
	Unipol	Gas Phase - Fluid Bed	Condensed
	Unipol	Gas Phase - Fluid Bed	Supercondensed
	Unipol II	Gas Phase - Fluid Bed	Bimodal
	Unipol Prodigy	Gas Phase - Fluid Bed	Bimodal
Various/Proprietary	Getech GMZ	Gas Phase - Fluid Bed	
	Nova	Gas Phase - Fluid Bed	
	SABIC	Gas Phase - Fluid Bed	Supercondensed
	Sinopec	Gas Phase - Fluid Bed	Condensed
	Sumitomo	Gas Phase - Fluid Bed - Staged	Bimodal
	Sumitomo	Gas Phase - Fluid Bed	

- While several are different variations of a basic scheme, it is important in competitor analysis to distinguish between them, and on a grade-by-grade basis

The Proliferation Of Technologies: Slurry Phase

Slurry Phase Processes

CP Chem	MarTECH SL	Slurry Loop Reactor - iso-Butane Diluent	Unimodal
CP Chem/Total	MarTECH ADL	Slurry Loop Reactor Cascade - iso-Butane Diluent	Bimodal
Ineos Technologies	Innovene	Slurry Loop Reactor - iso-Butane Diluent	Unimodal
	Innovene S	Slurry Loop Reactor Cascade - iso-Butane Diluent	Bimodal
Japan PE	CSTR Slurry	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Japan PE AMSLP	Slurry 3-Loop Reactor Cascade - iso-Butane Diluent	Multimodal
	Japan PE/Mitsubishi	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Japan PE/Nippon Oil	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Japan PE/Showa	Slurry Loop Reactor - iso-Butane Diluent	Unimodal
LyondellBasell	Equistar Slurry	Slurry Horizontal Loop Reactor - iso-Butane Diluent	Unimodal
	Equistar-Maruzen	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Hostalen	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Hostalen ACP	Slurry Stirred Tank - Hexane Diluent	Trimodal
Mitsui	Mitsui CX	Slurry Stirred Tank - Hexane Diluent	Bimodal
Various/Proprietary	Asahi	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Braskem	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Chisso/Amoco	Slurry Stirred Tank - Hexane Diluent	Bimodal
	FasTech	Slurry Stirred Tank	
	Getech SCZ	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Ruhrchemie	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Sinopec	Slurry Stirred Tank - Hexane Diluent	Bimodal
	Versalis	Slurry Stirred Tank	Elastomers

- Loop reactors are ascendant and are the basis for much of the new HDPE capacity being added in North America to 2020

The Proliferation Of Technologies: Solution Phase

Solution Phase Processes

Borealis	Borceed	Solution - Single Stage Adiabatic	Unimodal
Dow	Dowlex CSTR	Solution - Cooled Low Pressure Cascade	Bimodal
	Dowlex CSTR	Solution - Cooled Low Pressure Converging Cascade	Multimodal
	Dowlex II	Solution - Cooled Loop Reactor Cascade	Bimodal
ExxonMobil	Ethylene Elastomer	Solution - Cooled Low Pressure Cascade	Bimodal
FasTech	Ethylene Elastomer	Solution - Low Pressure	Mono/Bimodal
LyondellBasell	Equistar Solution	Solution - Medium Pressure Converging Cascade	Multimodal
Mitsui	Ultzex/Tafmer	Solution - Medium Pressure Cascade	Mono/Bimodal
Nova	Sclairtec	Solution - Medium Pressure Cascade	Mono/Bimodal
	Sclairtec AST	Solution - Medium Pressure CSTR Cascade	Bimodal
SABIC	SABTEC Compact	Solution - Single Stage Adiabatic	Unimodal
SK Innovation	Nexlene	Solution - Loop Reactor Cascade	Bimodal
Sumitomo	Ethylene Elastomer	Solution - Low Pressure Cascade	Mono/Bimodal

- Solution processes have great flexibility with respect to product range
  - Particularly in terms of composition, but also in the number of reactor grades a single reactor can viably make
    - But with some limitations in production of very high molecular weight grades
- Solution processes are used across the capacity scale from 50 kta to 500 kta per line, for both commodity and specialty grades
    - They are increasingly important in production of specialty plastomers & elastomers

The Complexities of Competition In PE Markets

- As discussed above, the competitive environment is a supply/demand matrix that is granular down to individual grades of PE made in each production line in the supply chain of a regional market
  - There are a total of 89 processes in use, 34 high pressure for LDPE and 55 low pressure for linear PE – HDPE/LLDPE/Plast & Elast
  - Each production line may make between 3 and 30 grades
  - Every producer may have a different market strategy for each of his production lines, even if two or more lines use the same technology
  - Every tactical move by one producer will have repercussions for effectively all of his competitors in the regional market, and in markets for several grades, not just the grade that is subject to the move.
- Competition, including cost competition, must be evaluated on a grade by grade basis

The Scope Of Competitor Analysis In PE

- There are theoretically an infinite number of portfolio options open to each producer, and examination of several strategic offensive and defensive options, or sets of options, will often be necessary
  - A thorough assessment of PE competitors in a market may require cost estimates of several tens of grades from multiple plants in the regional supply structure.
  - In order to make well-founded strategic decisions, a PE producer may need to make hundreds or even thousands of cost estimates for different PE grades from competing plants
  - Competitor analysis typically requires that all of the above must be evaluated for a number of price scenarios
- It is clear that a detailed, robust and flexible cost estimating system is required.
- The need for such a system in North America is imminent:
    - 4 new PE lines in 2016, 10 due in 2017 (plus debottlenecks), 5 in 2018/19 and another 5 in 2020+ (includes plastomers & elastomers)

A Means To Tackle This Complexity

- To address this complexity, EnerChemTek, in cooperation with Advanced Technical Support, Inc., is developing a web-based cost estimating application that meets these needs for grade-by-grade analysis of production costs from competing PE producers and competing process technologies.
  - It easily executes, stores and collates hundreds or thousands of cost estimates, and allows the analyst to compare and adjust these estimates as needed to reflect changing price environments and changes in product, process or catalyst technologies.
- The system contains a model of each relevant PE process comprising a process description, flowsheet, recipe generator and a process economics calculation module.
  - The recipe generator estimates resin characteristics (Mw, MWD, composition) and plant operating parameters for each grade to be considered.
  - The output is the estimated production cost tabulation for each selected PE grade plus summary details of production rates, materials & utilities consumptions, capital- & labor-related costs, and profitability.

Phase I Of System Development

- In the first phase of system development, models will be built for 14 of the most important PE production technologies

Process & Variations	Modeled On:	Product Range							Catalysts		
		Unimodal HDPE	Bimodal HDPE	LLDPE	VLDPE	Plastomers Elastomers	LDPE	EVA	Ziegler	Cr-Oxide	SSC
A. Gas Phase Processes											
1. Gas Phase Fluid Bed	Unipol	✓	✓	✓					✓	✓	✓
2. Gas Phase Fluid Bed	Innovene G	✓		✓	✓				✓	✓	✓
3. Gas Phase Fluid Bed Cascade	Spherilene C	✓	✓	✓					✓	✓	✓
B. Slurry Phase Processes											
1. Slurry Loop Reactor - iso-Butane Diluent	MarTECH SL	✓				✓			✓	✓	✓
2. Slurry Loop Bimodal Cascade - iso-Butane Diluent	Innovene S	✓	✓						✓	✓	
3. Slurry Loop Bimodal Cascade - iso-Butane Diluent	MarTECH ADL	✓	✓	✓					✓	✓	✓
4. Slurry Stirred Tank - Hexane Diluent	Hostalen ACP	✓	✓						✓		
5. Slurry Stirred Tank - Hexane Diluent	Mitsui CX	✓	✓						✓		
C. Solution Phase Processes											
1. Solution - Cooled CSTR Cascade	Dowlex	✓	✓	✓	✓	✓			✓		✓
2. Solution - Cooled Loop Reactor Cascade	Dowlex II	✓	✓	✓	✓	✓			✓		✓
3. Solution - Medium Pressure Cascade	Sclair	✓	✓	✓	✓	✓			✓		✓
D. High Pressure Free Radical Processes											
1. High Pressure Tubular Multizone	Lupotech T						✓	✓			
2. High Pressure Compartmented Autoclave	Versalis						✓	✓			
3. High Pressure Autoclave Cascade	Sumitomo						✓	✓			

  – Models for Borstar, Evolue, Hyperzone & Sinopec gas phase, the triple-loop slurry, and Sabtec Compact & SK Nexlene solution processes will be added.

Standard Grade Definitions Or User Defined

Standard Grade Variations	
HDPE Blow molding - Bottle grade - C4, C6	MDPE Extrusion - C4, C6
HMW HDPE Blow molding grade - C4, C6	MDPE Rotomolding
HDPE Film - Cast	LLDPE Film - C4, C6, C8
HMW HDPE Film - Blown	mLLDPE Film - C6, C8
HDPE Injection Molding	LLDPE Injection Molding
HDPE Injection Molding - Bimodal	LLDPE Rotomolding - C4, C6, C8
HDPE Pipe - PE100	mLLDPE Rotomolding - C6, C8
HDPE Pipe - PE80	Plastomers - C4, C6, C8
HDPE Pipe - Unimodal	Elastomers - C4, C6, C8
LDPE Homopolymers - Film & Extrusion	EVA Copolymers - 3% to 36% VA

- For other grades, the user may enter a new grade definition by specifying basic properties such as melt index, density, application or other structure indicators such as narrow MWD, unimodal, bimodal, etc
  - The recipe generator translates these data into a custom cost estimate for the user-defined grade, including factors such as production rate, estimated composition, utilities consumptions, etc.

A Uniquely Useful Contribution To Knowledge Of The Polyethylene Industry

- In summary, this is a unique cost modeling platform and associated interactive web-based analysis service
  - An exclusive, independent & publicly available source that provides the flexibility of use and the relevant depth of technical information required for detailed competitive analysis in the PE production industry.
    - The interactive ability to compare costs for essentially any user-defined grade of PE made in plants of any size & configuration using any process and catalyst technologies on a directly comparable basis
    - Extremely useful both in selecting technology for a new production facility, and in assessing the competitive strengths of existing and future suppliers to regional PE markets.
- The PE process & cost analysis system is currently under development, together with the associated web-based support & delivery system
  - Beta version available after 3-4 months
  - Full availability H2, 2017
  - Currently enrolling subscribers