ALBERTA

POLYSTYRENE PRODUCTION

OPTIONS

Prepared for

ALBERTA ECONOMIC DEVELOPMENT

By

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Disclaimer

The contents, conclusions, recommendations and calculations in this report are the sole responsibility of Harry Blair Consultants and associated consultants. They may or may not be in agreement with the views and/or policies of Alberta Economic Development. As well, please note that this report has been completed without consultations with Shell Chemicals Canada Ltd., and potential PS producers.

Glossary

AAI	Average Annual Increase
ABS	Acrylonitrile-Butadiene-Styrene resin
CCA	Capital Cost Allowance
CMAI	Chemical Market Associates Inc.
Distn.	Distillation
EB	Ethylbenzene
EDC	Ethylene Dichloride
EG	Ethylene Glycol
EP	Earning Power
EPS	Expandable Polystyrene
EVA	Ethylene Vinyl Acetate
FOB	Free On Board
GDP	Gross Domestic Product
HDA	Hydrodealkylation
HDPE	High Density Polyethylene
ISBL	Inside Battery Limits
K	Thousand
KTA	Kilotonnes per Annum
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
M	Million
MW	Molecular Weight
NOVA	NOVA Chemicals Corporation
NPV	Net Present Value
OSBL	Outside Battery Limits
PE	Polyethylene
PO	Propylene Oxide
PS	Polystyrene
PP	Polypropylene
R.O.W.	Rest of the World
SAN	Styrene-Acrylonitrile resin
S/B	Styrene-Butadiene latex
SBR	Styrene-Butadiene rubber
SCCL	Shell Chemicals Canada Limited
SCL	Shell Canada Limited
SM	Styrene Monomer

SPS	Syndiotactic Polystyrene
USGC	United States Gulf Coast
UV	Ultra Violet
VA	Vinyl Acetate
VCM	Vinyl Chloride Monomer
XPS	Expanded Polystyrene

1.0 EXECUTIVE SUMMARY

Alberta Economic Development commissioned the proposed study, “Alberta Polystyrene Production Options”, to identify the economic benefits of establishing polystyrene production in Alberta.

The rapid growth of the Alberta petrochemical industry since the mid-1970’s was the result of the creation of a positive environment by the provincial government in its desire to diversify the provincial economy, and significantly increase the value added to resources in the province. This positive climate has been fostered by:

- a stable political environment,
- a competitive tax regime,
- a healthy fiscal policy, and
- an efficient regulatory process.

Whereas the ethylene derivative chain has flourished in the province since the 1970’s, the benzene derivative chain has grown slowly, with current investments by Shell Chemicals Canada Ltd. (SCCL) at Scotford, in the form of a world scale styrene monomer (SM) facility, and by Plasti-Fab Ltd. division of PFB Corporation at Crossfield, in the form of expandable polystyrene (EPS) production and consumption. Limitations on benzene availability and a smaller “Alberta Advantage” for crude- versus natural gas-derived products are two of the reasons why styrene derivatives have not thrived in Alberta.

Several business efforts to bring world scale polystyrene (PS) facilities to Alberta have been mounted since the start up of the SCCL SM plant in 1984. However, success has eluded each attempt to date. In the light of such a history, Alberta Economic Development has commissioned this report to better understand the economic realities of PS production in Alberta.

The top three PS producers in the world are:

- Dow Chemical
- NOVA
- BASF

Of these producers, Dow and NOVA are the most active members of the Alberta petrochemicals group of companies, and are the most natural candidates for a PS project in Alberta.

An economic model was developed to evaluate the profitability of constructing and operating a crystal/impact PS plant in Alberta, using local SM as feedstock, and shipping the product to consumers in Alberta, North America and Asia. The model takes input as project costs (capital and expense), inflation, operating rates, feedstock and product prices, logistics costs, corporate tax rate and GDP deflator; and generates the Net Present Value (NPV) of a stream of real cash flows at a given discount rate, as well as the project earning power (EP).

The base case assumed that the major premises of Table 13 (Page 36) apply, that all future real cash flows were discounted at 8% per annum, and that all transportation savings accruing to SCCL, as a result of supplying SM to a nearby location versus the usual costs of supplying to a slate of current customers, are transferred to the PS producer as a discount off the SM market price.

The results of this base case were an attractive NPV, and a strong real EP as shown below.

The base case results were as follows:

- **NPV_8 = $54 million**
- **Earning Power = 16.1%**

Since the base case project profitability is quite attractive the authors have determined that an Alberta-based PS project could be successful, assuming that the project utilizes modern, efficient process technology, is world scale (at least 100KTA), is located on a brownfield site, and has access to competitive styrene feedstock with discounts of one or two US c/lb (not unusual in the North American marketplace), in addition to the SM transportation savings. Such additional SM discounts place project profitability in a range of 18-20 % earning power. Even without additional styrene discounts, the project has an earning power of 16% and warrants a hearing at any corporate board on its own merits. Such real, after tax earning powers establish such a project as attractive and worthy of further evaluation by candidate production companies.

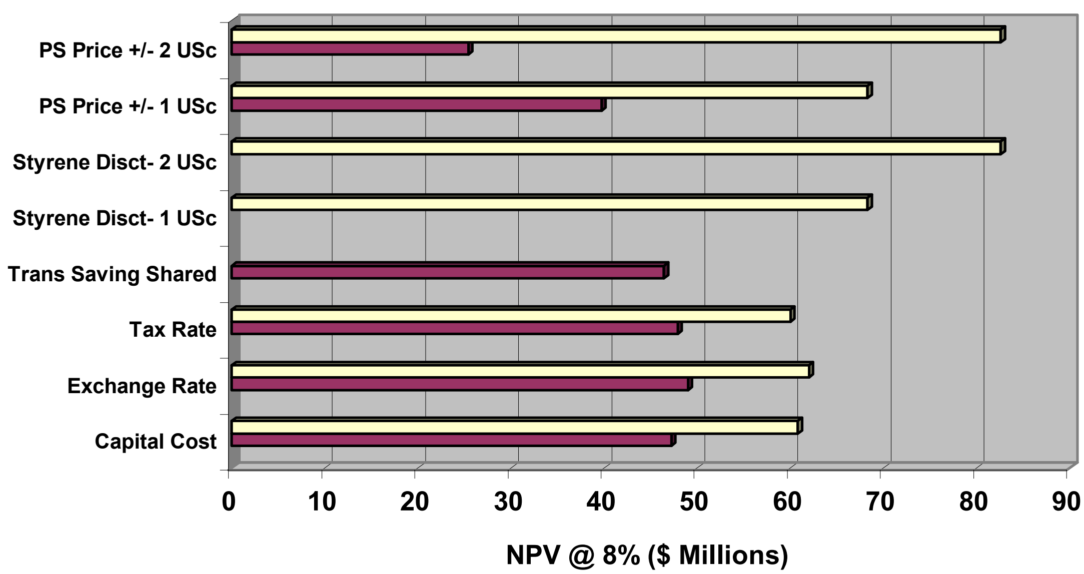
Base Case Plus Additional 2 USc/lb:

- **NPV_8= $82.6 million**
- **Earning Power = 19.6 %**

The project profitability sensitivities are summarised in Figures 12 and 13 and indicate that, for the subject PS project to merit further detailed economic evaluation and eventual process design and construction, SM price discounts may not be necessary. As well, capital costs must be maintained at or near those on the USGC, and all CCA's must be written off immediately against existing income streams, i.e., the PS plant owner will require current operating assets in Alberta.

Project Earning Power Sensitivities

Project NPV Sensitivities



In Section 7.4, the economics of an SM cash cost case was investigated. The SM cash cost was input to the PS project, with all profits of such a case being assumed by the PS business. This effort allowed us to identify the profitability of using such SM as feedstock for PS throughout the project life. Transportation savings of shipping styrene locally are not included in this evaluation. The results, the maximum profitability for the PS project, are as follows:

Cash Cost Styrene to the PS Project

NPV_8 = $154 million

Real Earning Power = 27%

SCCL is the only SM manufacturer in Alberta, and is critical to any PS project mounted in the province. Just as SCCL would be the only supplier of SM to the project, the project would most likely become the largest single site consumer of SCCL's Scotford SM. With such potential synergy available, any PS producer would consider including SCCL in an SM supply agreement that gives SCCL access to PS profits above a set level, throughout the life of the long term supply agreement

If, for whatever reason, SCCL could not divert 100 KTA of SM from current markets, there might be a case for it to expand its existing facility to provide the additional 100 KTA of SM. The authors assume, for use in calculations, that such an addition would cost SCCL approximately $50 million in capex.

Such a requirement would truly result in a partnership, wherein SCCL would invest approximately $50 million in additional SM production facilities at Scotford, while the new PS company would invest approximately $90 million in the new PS plant and ancillaries. Thus, the total investment commitment will be $140 million.

Using the same cash cost approach for the SM produced from the SM expansion (100KTA of SM), supplying such advantaged SM to produce 100 KTA of PS, the profitability of such a combined venture has to be spread over the two projects. With the same model inputs as for the base case of the PS project, but with the capital cost now at $140 million ($90 million for PS and $50 million for SM), the SM transportation savings removed, and cash cost for the 100KTA of SM required for the project, the economic results are as follows:

Evaluation of Combined SM Expansion and PS Projects

NPV_8 = $120 million

Real Earning Power = 19%

Such an expansion of styrene by Shell requires approximately 80 KTA of additional benzene as feed. The authors are aware that the additional supply of Alberta-based benzene might be a constraint to such an expansion.

Assuming that such economic results meet the criteria of the parties, then the benefit from the combined projects could be shared between the parties according to the capital expended by each, and be backed by a long term agreement to supply and to purchase 100 KTA of SM.

The mechanism for sharing the benefit on the project would be in the form of an SM price in such long-term agreement equal to the cash cost of SM plus SCCL's capital-based share of the margin between the PS netback to the PS producer, and the SM cash cost.

The authors believe that this partnership opportunity warrants discussions with SCCL and detailed economic evaluation by SCCL and by candidate PS producers.

2.0 INTRODUCTION

2.1 Terms of Reference

Alberta Economic Development commissioned the proposed study, “Alberta Polystyrene Production Options”, to identify the economic benefits of establishing polystyrene production in Alberta.

Shell Chemicals Canada Ltd. has been operating a world scale styrene monomer facility at Scotford, Alberta, since 1984. However, since that time, there has been only one successful polystyrene development in the province – that of Plasti-Fab Ltd., a division of PFB Corporation, located in Crossfield. Since 1984, several investigations have been made by industry into polystyrene manufacture in Alberta, without success. Alberta Economic Development has requested that the possibility be revisited, with details of economic drivers, potential candidates for construction and operation, and key assumptions that would determine the success of such a venture.

The proposed study was to review the existing polystyrene businesses in Alberta, and in North America in general, with their relationships to styrene monomer, and to highlight the chemistry of polystyrene, with specific production processes identified.

Details of the study process are given as follows:

The North American polystyrene business was to be reviewed to present:

- Producers and locations
- Plant sizes
- Processes utilized
- North American supply/demand
- Major end-uses and growth
- Forecasts of growth for each end-use

Existing Alberta styrene monomer (SM) and polystyrene (PS) production facilities and infrastructure were to be identified, with specific attention given to the Shell Chemicals Canada SM plant at Scotford; the Plasti-Fab expandable polystyrene (EPS) facilities at Crossfield; and, the Dow Chemicals Canada foamed PS facilities at Fort Saskatchewan. Advantages and disadvantages of Alberta SM and PS production were to be reviewed, with possible limitations on SM production expansions discussed.

Available PS processes will be described, with suggested choices suited to Alberta’s requirements. Possible economic scale will be proposed, with forecast feedstock requirements and costs.

The study will propose examples of PS processes and plant sizes for the Alberta location (brownsite suggested), and will indicate freight costs for SM and for PS to various consuming locations.

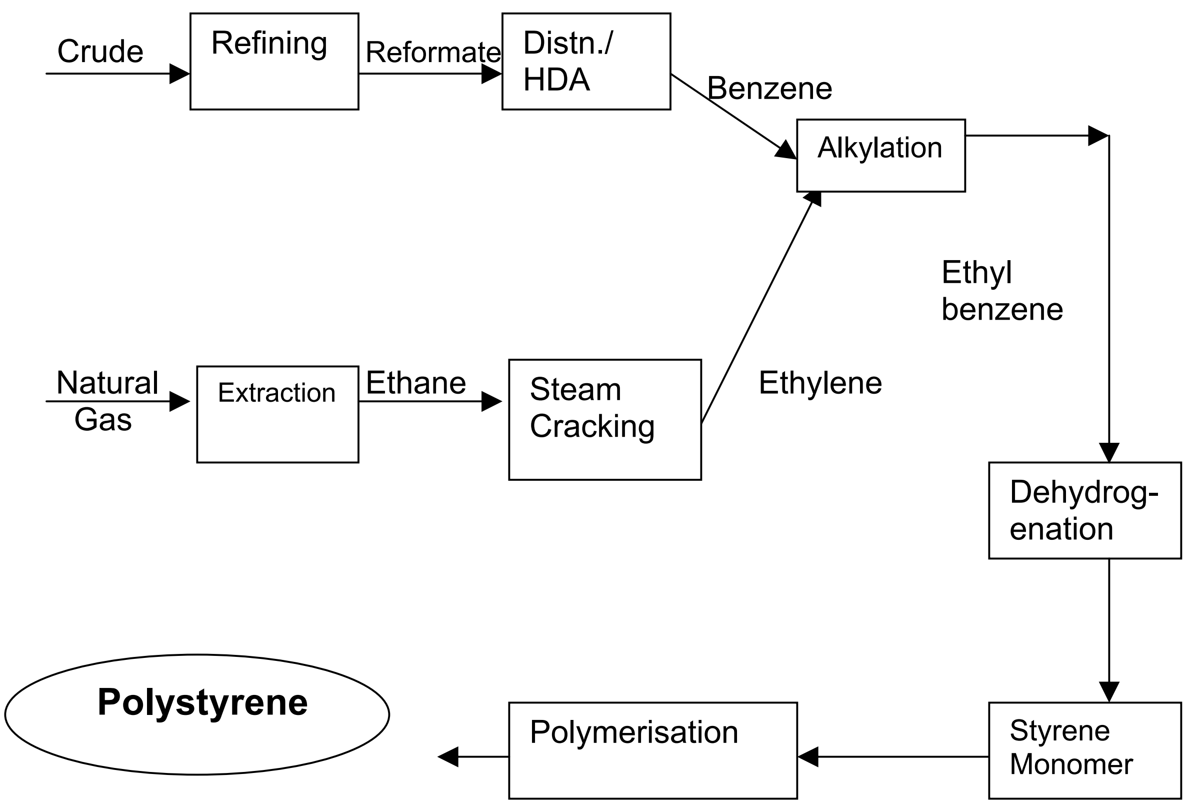
We will prepare a general economic proposal for producing PS in Alberta, with such production compared with producing SM and shipping to customers across North America and Asia, for production of various SM end-uses, including PS.

The study will suggest possible PS producers and/or potential partnerships for such production. Production of more than one PS product type on the same site will be investigated.

3.0 SM/PS CHEMISTRY AND CHEMICAL PROCESSES

A schematic representation of the steps involved in the main route to the formation of SM, the precursor to PS, is shown in the following, Figure 1. In order to give this an Alberta context, the sources of the benzene and ethylene are also shown.

Figure 1 Schematic for SM/PS Production



In Alberta, benzene is produced in the refinery owned and operated by Shell Canada Ltd. (SCL) at Scotford. Mixed aromatics (benzene, toluene, and xylenes) are extracted from reformate, produced in the refinery process, and fractionated into benzene and toluene/xylenes streams, the latter being converted to additional benzene in the hydrodealkylation (HDA) unit. The resulting benzene streams are consolidated and purified for subsequent use in the EB unit.

Ethylene is produced by cracking ethane in the ethylene plants owned and operated by NOVA (at Joffre) and Dow (at Fort Saskatchewan).

EB is produced by Shell Chemicals Canada Ltd. (SCCL) at Scotford, from the above benzene and ethylene using Mobil's technology, and subsequently converted to SM using Badger technology.

3.1 EB Production

EB, the precursor for SM, is obtained by the alkylation of benzene with ethylene. The chemical representation of this reaction is as follows:

C6H6	+	CH2=CH2	→	C6H5-CH2-CH3
Benzene		Ethylene		Ethylbenzene

This reaction takes place either in the liquid phase at modest temperature and atmospheric pressure using aluminum trichloride as catalyst (continuously added), or in the vapour phase using a fixed bed zeolite catalyst. The former method is the historic route, but suffers, among other things, from the highly-corrosive hydrochloric acid released from the aluminum trichloride in the presence of moisture, resulting in the need to use sophisticated materials of construction in order to minimize corrosion problems; and the need to dispose of significant quantities of aluminum hydroxide formed in the process. The zeolite catalysed process uses a fixed bed system which only needs to be topped-up or replaced on an intermittent and planned basis, and is the technology of choice for recently-constructed plants.

The EB is purified to about 99% to be used as feedstock for SM.

In the majority of cases, EB production is used for on-site conversion to SM. Very little EB is traded geographically.

3.2 SM Production

The predominant process used to produce SM involves the high temperature dehydrogenation of EB in the presence of a catalyst. The chemical representation of this reaction is as follows:

C6H5-CH2-CH3	→	C6H5-CH=CH2	+	H2
Ethylbenzene		Styrene monomer		Hydrogen

In most cases the catalyst is a form of iron oxide carried on an inert substrate in the form of small extruded granules. The catalyst is a fixed bed, and is replaced on a routine basis at 2 to 3 year intervals. Benzene and toluene are co-produced in the process. The benzene is recycled to the EB unit, and the toluene sold, or recycled to a hydrodealkylation (HDA) unit to be converted again to benzene.

Another process being used increasingly involves co-production with propylene oxide (PO), and is referred to as the SM/PO (Shell), or POSM route. In this process, EB is oxidized to ethylbenzene hydroperoxide, which in turn is reacted with propylene to yield PO and methylphenylcarbinol. The methylphenylcarbinol is then dehydrated to SM.

Dow has a process which converts butadiene to SM in a two stage process via vinylcyclohexene, using different zeolite catalysts in each stage, but this route is still not in commercial use.

Monsanto has patents on a further process in which toluene is reacted with ethylene at high temperature (500-600 C) in the presence of a catalyst and oxygen. Again this process has not yet been commercialized.

SM is used almost exclusively (about 94%) as the feedstock for a wide variety of homopolymers and copolymers (e.g. ABS resins, S/B copolymer latexes, SBR elastomers and latexes, unsaturated polyester resins, and SAN resins). Because the capacity of these polymer plants is only in the 10 to 100 KTA range, SM is shipped extensively to both short-, and long-haul destinations.

3.3 PS Production

The reactive chemical intermediate SM is the immediate precursor for all forms of PS. The polymerization reaction is represented as below:

```
x  CH=CH2      ------>    --[--CH-CH--]—
    /                          /         x
   C6H5                       C6H5

 Styrene monomer              Polystyrene
```

The three main, commercially available, types of PS are Crystal PS, Impact PS, and Expandable PS. In these three types, the molecular structure is atactic, i.e. the phenyl (C6H5-) groups are randomly placed on either side of the polymer chain. Polymerisation is effected by a free radical mechanism, and can be initiated by heat alone, or more effectively by heating in the presence of a free-radical provider, such as benzoyl peroxide. The polymerization of SM is highly exothermic, and the properties of the polymer are governed by control of catalyst concentration, temperature, and time of the reaction.

Syndiotactic polystyrene (SPS), in which the phenyl groups alternate regularly from one side of the polymer chain to the other, are produced using metallocene catalysts similar to those used for polyolefins. SPS has some superior properties compared to atactic polymers, but is still only commercially available in small quantities.

The third possible structure for polystyrene is isotactic, in which the phenyl groups are all situated on the same side of the polymer chain. Isotactic PS polymers can be produced using Ziegler-Natta catalyst systems, but are not commercially viable due to their slow rate of crystallization.

3.3.1 Crystal PS

Historically, Crystal PS was produced by batch polymerization of SM suspended in water. Agitation (stirrer speed) and suspension agents control the bead size, and the heating cycle and catalyst control the molecular weight (MW) and MW distribution, which in turn determine the PS properties. The resulting beads are then converted, by extrusion, into strand-cut granules. In this stage, the properties of the PS are further influenced by incorporation of UV stabilizers, anti-static agents, flame-retardants, etc. These granules are the form in which the product is shipped and sold.

Although Crystal PS is still produced as described above, there is an increasing tendency to use continuous mass polymerization, with a series of stirred reaction vessels, and heat-exchange zones to control the reaction temperature. The resultant hot polymer is fed to an extruder, where the additives package is introduced, and strand-cut granules produced for subsequent shipping and sale.

Crystal PS, in addition to other applications which will be addressed later, is also the feedstock for the production of foam board by extrusion. The beads are mixed with a solid foaming compound which releases the blowing agent at the extruder temperature, and produces the foaming effect at the die-plate.

Crystal PS polymers have high clarity and stiffness and are used for cup, tumbler, and cassette and CD cases. They are also chemically inert and water-resistant, and thus have an advantage in electronics, food, automotive and medical applications.

3.3.2 Impact PS

Impact PS is produced by incorporating small proportions of polybutadiene elastomers into the PS. High Impact grades typically include 6-12 % elastomer, and Medium Impact grades contain 2-5%. The elastomer is dissolved in the SM, and the mass polymerization process as described above is used to produce copolymers with the required properties.

As the name suggests, these products are more impact resistant than Crystal PS, and compete with polyethylene and polypropylene products in some applications.

Impact PS polymers are used in appliance and electronics housings such as refrigerator linings and TV cases.

3.3.3 Expandable PS (EPS)

EPS in the form of beads is produced by the batch suspension polymerization of SM as described in Section 3.3.1. In the latter stages of the production cycle, the reactor is closed, the blowing agent introduced, and the reactor temperature increased. Under these conditions, the blowing agent (usually a saturated aliphatic hydrocarbon in the C4 to C6 range) is absorbed into the beads, where it remains when the reactor contents are cooled and removed. In further continuous processing, the beads are dried, sieve-cut into the bead size ranges for the particular application, and packed into sealed containers in order to maintain the blowing agent content. This is the form in which the product is shipped and sold.

The EPS beads are steam-expanded by the fabricator into Expanded PS (XPS) beads. Generally, the largest bead cuts are moulded into large blocks, and then cut into sheets for thermal insulation; medium beads are moulded to shaped protective packaging; and small beads are used for moulding into disposable drinking cups.

4.0 NORTH AMERICAN PS BUSINESS

4.1 Market Definition and Characterisation

4.1.1 World

As in several other business sectors, the PS business has been characterized in the North American and European regions over the last 4 to 5 years by consolidation of ownership and closure of several small regional production facilities. In January, 1996, five companies, Dow, BASF, Huntsman, Fina, and NOVA owned 35% of World capacity. During the past 4 years, NOVA has been the most active in asset acquisition as it pursued a strategy to become the lowest-cost commodity petrochemical producer in ethylene/polyethylene and styrene/PS. In this period, NOVA's purchases were:

- during 1996, the PS assets of Arco at Beaver Valley, PA, and Painesville, OH;
- in December, 1998, the Crystal and Impact PS manufacturing assets of Huntsman at Belpre, OH, Chesapeake, VA, Joliet, IL, Peru, IL, and Carrington, UK, together with Huntsman's EPS facility at Ribecourt, France;
- in January, 2000, Shell's Crystal/Impact PS, and EPS plants at Breda, the Netherlands, and EPS plants at Carrington, UK, and Berre, France.

As a result of the above, together with some plant expansions, and closures (see below), over this period NOVA's total PS capacity increased more than three-fold, from about 550 KTA to its current level of 1720 KTA.

Although Dow and BASF have continued to expand and add new capacity, NOVA's activity has improved its global ranking to second-largest EPS producer, and third-largest solid PS producer.

This consolidation has resulted in the top 3 producers, Dow, BASF, and NOVA now holding about 35 to 40% of world capacity.

PS production locations tend to be geographically widespread but close to the consumer demand, and the plants relatively small compared to those of polyolefins, and other commodity petrochemicals. For example, average plant sizes are 80, 110 and 50 KTA for crystal PS, impact PS, and EPS respectively. However, there are some large facilities (may be multi-line) such as Fina's crystal (180 KTA), and impact (280 KTA) assets at Carville, LA; BASF's crystal/impact plants at Ludwigshaven, Germany (345 KTA), and Antwerp, Belgium (220 KTA); and the EPS plants of NOVA at Beaver Valley (170 KTA), and BASF at Ludwigshaven (180 KTA).

Plant closures have been made over the past 2 to 3 years in the US as shown in Table 1 below:

Table 1 Recent Closures of PS Plants in the USA

Company	Location	Capacity (KTA)	Closure Date
BASF	Holyoke, PA	32	Nov/1997
	Santa Ana, CA	34	Dec/1998
Huntsman	Rome, GA	18	1997
NOVA	Addystone, OH	36	Dec/1997
	Peru, IL	54	Oct/1999
	Willow Springs, IL	32	1998

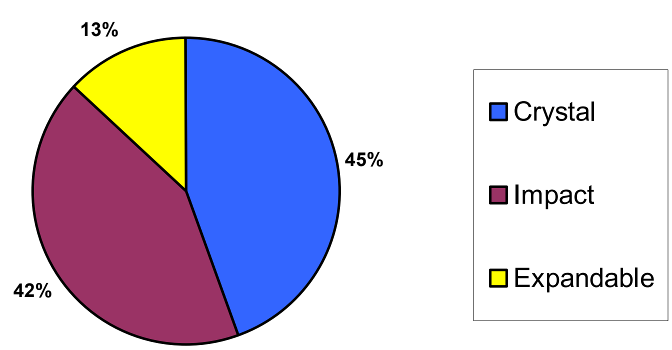
Note: All the above plants produced solid PS, except the EPS facility of Huntsman at Rome, GA

4.1.2 North America

In North America (USA, Canada, and Mexico), the distribution between the three main PS resin types is as shown in Figure 2 below:

Figure 2 Breakdown of North American Capacity for the Three Main PS types, 1998

Total production = 3.79 million tonnes



4.1.3 Canada

In order for a PS investment in Alberta to come to fruition, it will have to be founded on a continuation of the advantages under which the existing world-scale petrochemical industry has developed and flourished in the province since the mid-1970's:

- feedstock at advantaged price and with secure availability to offset the negative geographical influences, i.e. distance from, and therefore transportation cost to, markets, and the small size of the manufacturing base relative to other petrochemical centers
- competitive construction costs for world-scale plants
- a stable political environment
- a competitive tax regime
- a healthy fiscal policy
- an efficient regulatory process
- a well-educated and skilled operating and maintenance workforce with a positive attitude
- a continuous supply of well-qualified graduates
- attractive legal and insurance costs
- trade arrangements (FTA and NAFTA)

As a result, this report will:

- concentrate on the North American market
- consider the western North American region, in which an Alberta PS investment would suffer least erosion of the feedstock, and other manufacturing advantages
- be limited to the relatively large-scale major PS forms, crystal, impact, and expandable
- not consider other copolymers (e.g. SBR, ABS, etc) as they involve importing feedstocks to the province, and small plant sizes

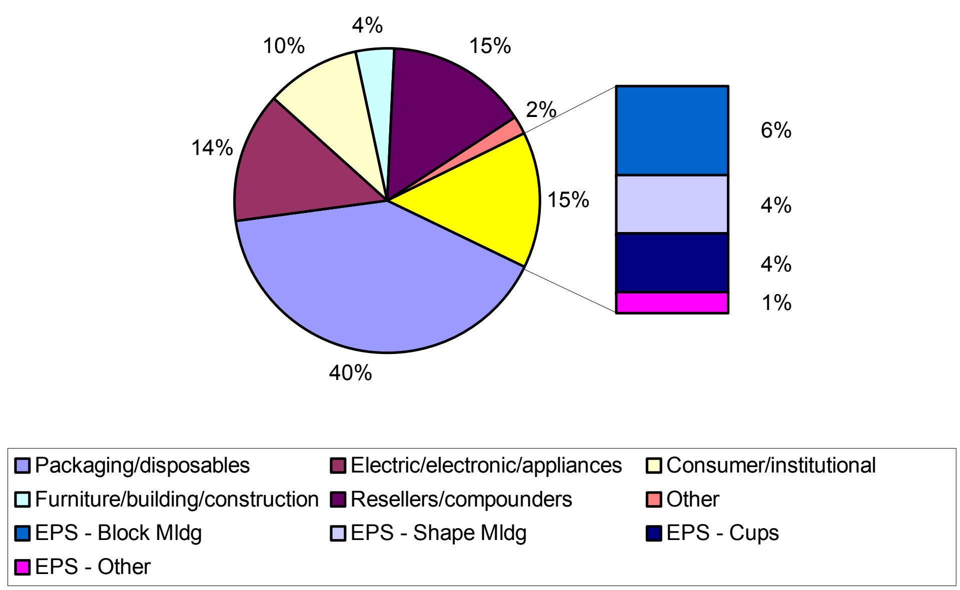
4.1.4 Western North America

For the purposes of this report, the western North American market is defined as the area west of the Mississippi River in the US, but excluding Texas, Louisiana, Arkansas and Oklahoma, and the western Canadian provinces Manitoba, Saskatchewan, Alberta, and British Columbia.

4.2 Major End Uses and Growth

Breakdown of consumption of all PS types by end-use application in the US is considered representative of the North American market, and is shown in Figure 3 below for 1996:

Figure 3 US Consumption of PS by End-use Application, 1996



Growth in consumption of PS in North America is expected to average 3.2% AAI over the period 1996 to 2001. The highest rates are expected in medical articles (5%), electronic and electrical uses (4.8%), and EPS beads in building and construction (4%). The difference in growth rates (see Table 2 below) does not significantly affect the distribution between the major application groups shown in Figure 3 above.

Table 2 Forecast Growth Rates for PS End-use Applications, North America, 1996 to 2001

End-use Application	AAI (%)	Remarks
Packaging/Disposables	3.2	
Electrical/Electronic/Applications	3.4	Electrical/Electronic, 4.8%
Consumer/Institutional Products	3.5	Medical Articles, 5%
Construction/Building/Furniture	2.4	
Resellers/Compounders	3.2	
EPS beads	3.1	Building/Construction, 4%
Other	2.0	
TOTAL	3.2	

4.2.1 Interpolymer Competition

PS competes with the polyolefin resins, HDPE, LDPE, LLDPE, and PP in several processing/end-use applications. Table 3 shows the USA consumption of polyolefins and polystyrene in various processing categories for 1999.

Table 3 End-uses of polyolefins and polystyrene in the USA, 1999 (KTA)

	HDPE	LDPE	LLDPE	PP	PS	TOTAL
Film	999	1289	2220	602	45	5155
Blow molding	1985	34	9	98		2126
Injection molding	1073	138	286	1715	1200 (1)	4412
Extrusion coating	40	463	23			526
Rotomolding	68	2	318			388
Other extrusion	989	202	171	59	649 (2)	2070
Sheet				92	327 (3)	419
Fibre/filament				1764		1764
Compounder & reseller	576	300	425	975		2276
Steam molding					401 (4)	401
All other	189	170	99		177	635
TOTAL	5919	2598	3551	5305	2798	20171

Notes:

(1) Includes blow molding
(2) Includes some Building and Construction applications
(3) Extruded foam
(4) EPS beads for Packaging and Insulation

The main competition for PS is PP. Historically, the price of PS exceeded that of PP by 9 to 15 USc/lb, and precluded the use of PS in some applications where either polymer can be used. However, since the mid-1990's the differential has eroded as the price of propylene has escalated due to high demand growth. At the same time, the prevailing use of the toluene disproportionation route to p-xylene (to meet demand for PTA and subsequently PET), in which benzene is coproduced, has increased benzene supply. With benzene demand showing little growth, benzene price has remained soft, and SM and PS prices have not maintained the historical premium over PP. As a result, there may be opportunities for PS to capture some traditional PP applications.

Some end-uses are specific to each polymer. Because PP elongation is up to ten times that of impact PS, it is the preferred product for fibre and filament applications. Crystal PS, with better stiffness and clarity than PP, is the preferred polymer for glass-replacement and cutlery end-uses. PP's chemical resistance leads to its use in pipe and conduit fabrication, and battery cases. Impact PS extruded sheet is as tough as PP, more easily thermoformed, and used for refrigerator liners.

PS has advantages over the other polymers in foam and expanded bead applications, because of its relatively low base polymer cost, and low processing costs.

4.3 Supply/Demand

4.3.1 World Supply/Demand

In 1996 the total global production capacity for PS, i.e. solid and expandable, was about 13.98 million tonnes, and the global consumption was about 10.73 million tonnes. The distribution of this capacity and consumption between the North American (USA, Canada, and Mexico), European (West and East), Asian (Japan, Republic of Korea, Taiwan, PRC, Hong Kong, and other Far East countries), and the Rest of the World (R.O.W.--Central and South America, Africa, Middle East countries, and Oceania) regions is shown in Table 4, below:

Table 4 World Capacity and Consumption of Polystyrene, 1996

(million tonnes)

	Capacity	Consumption
North America	3.66	2.91
Europe	4.09	2.90
Asia	5.42	4.15
Rest of World	0.81	0.77
TOTAL	13.98	10.73

[Source: C E H, Marketing Research Report , "Polystyrene", April, 1998]

Both global capacity and consumption are forecast to increase, and by 2001 are expected to reach 16.25 and 13.33 million tones per year, respectively. The change in the regional breakdown of both capacity and consumption is shown in Figures 4 and 5 respectively below:

Figure 4 Changes in Regional PS Production Capacity, 1996 to 2001 (%).

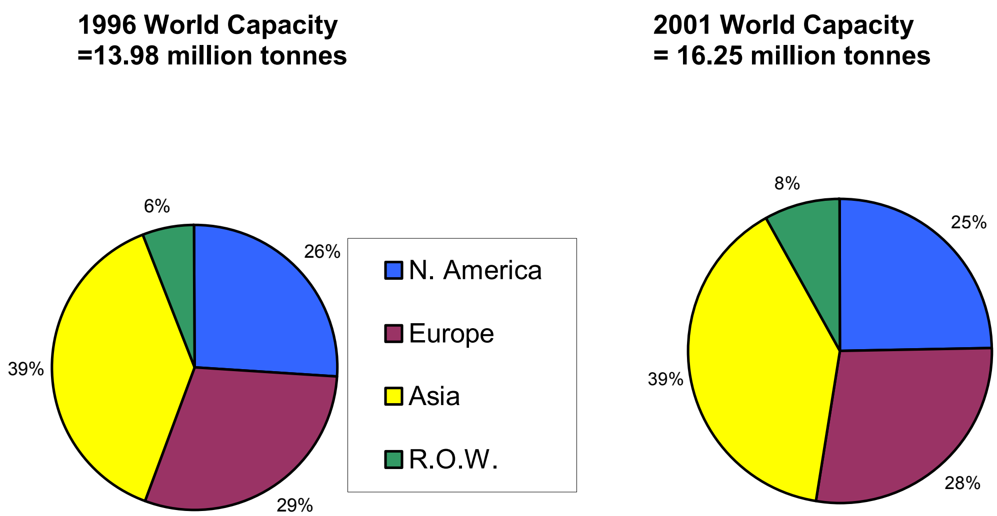
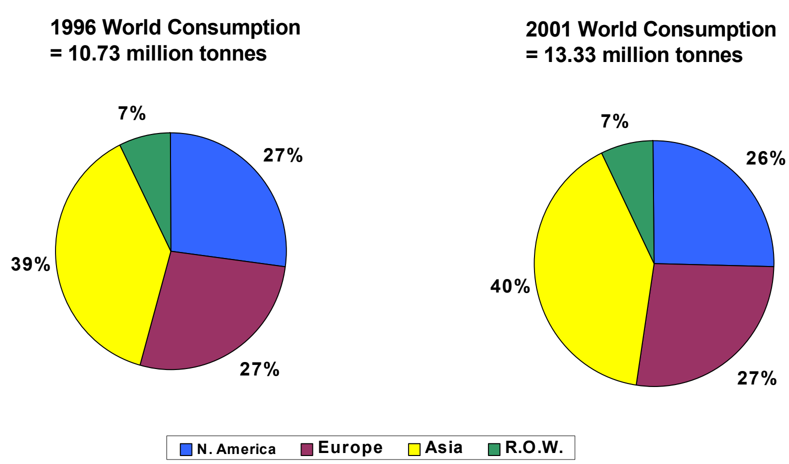
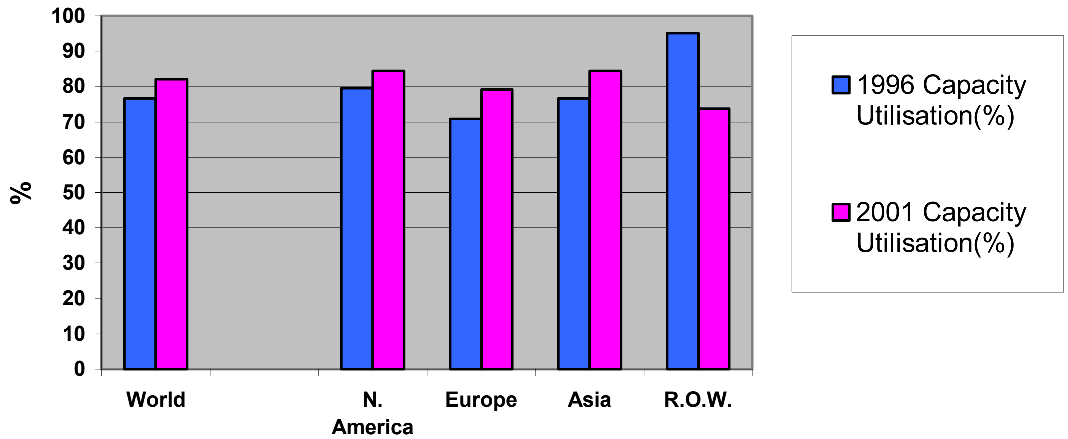


Figure 5 Change in Regional PS Consumption, 1996 to 2001



Determination of “Capacity Utilisation”, the ratio of consumption to capacity, for the total World suggests a significant increase from about 77% in 1996 to about 82% in 2001. The regional distribution indicates improvements in Capacity Utilisation in the North American (80 to 84%), European (71 to 79%), and Asian (77 to 84%) regions, while the R.O.W. Capacity Utilisation falls from 95 to 74%. This data is shown in Figure 6 below:

Figure 6   Changes in World & Regional PS Capacity Utilisation, 1996 to 2000



The reason for the suggested increasing Capacity Utilisation in the North American, European, and Asian regions is that although there are forecast to be capacity expansions or additions in these regions, the rate of increase in consumption, 3 to 5.5% average annual increase (AAI), is forecast to exceed the rate of increase in capacity, 2 to 3.5% AAI. In the R.O.W., the rate of increase in capacity, 10.5% AAI, is expected to greatly exceed the rate of increase in consumption, 5% AAI. As a result, these countries will increasingly be net exporters to the other regions. This data is shown in Table 5 below:

Table 5 Comparison of Growth in Capacity and Consumption of PS

1996 to 2001

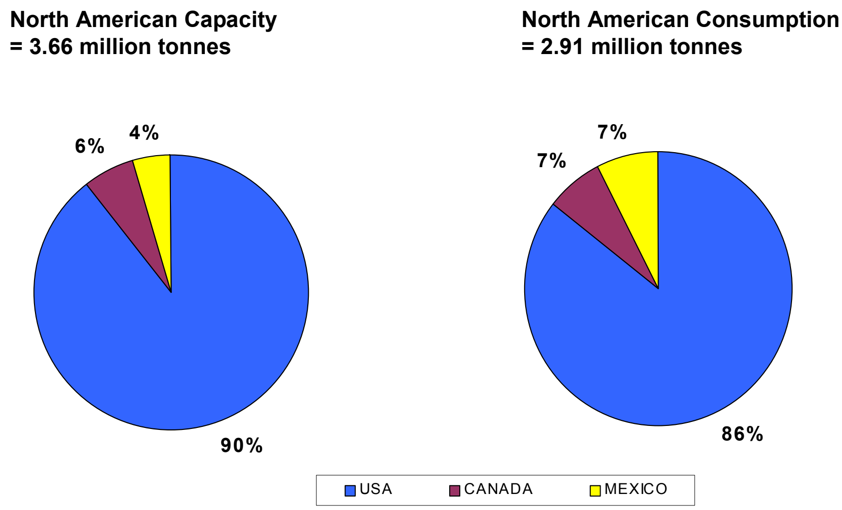
	Capacity Change		**Consumption Change**	
	Million tonnes/yr	**AAI (%)**	**Million tonnes/yr**	**AAI (%)**
North America	0.37	2.0	0.49	3.1
Europe	0.41	2.0	0.66	4.2
Asia	0.97	3.4	1.24	5.4
R.O.W.	0.52	10.5	0.21	5.0
TOTAL	2.27	3.1	2.60	4.5

[Source: C E H, Marketing Research Report , “Polystyrene”, April, 1998]

4.3.2 North American Supply/Demand

The North American region is dominated by the production and the consumption in the USA. In 1996, 90% of the capacity and 88% of the consumption was located in the USA. Canada represents just over 6% of production, and slightly less than 6% of consumption, and is a small net exporter; Mexico contributes less than 5% of North American production, and about 5.5% of consumption, i.e. is a small net importer. Figure 7, below, shows the distribution of capacity and consumption between the three countries for 1996:

Figure 7 North American PS Capacity & Consumption, 1996



By 2001, with planned incremental capacity increases in each country, the North American capacity shares of Canada and Mexico will increase by about 0.5 and 3% respectively, with the US share correspondingly reduced by about 4%. However, the shares of consumption in each country will change very little, and Mexico will become a more significant exporter.

4.3.3 Canadian Supply/Demand

As of January I, 1998, Canadian capacity to produce the three PS types was 240 KTA. Of this, 41 KTA was EPS, 60 KTA dedicated crystal PS, and 140 KTA crystal/impact. With actual production of 207 KTA in 1997, the capacity was being operated at a utilization rate of 94%. Domestic consumption at this time was about 175 KTA, with net exports of about 32 KTA (imports 73 KTA, and exports 105 KTA).

With ongoing capacity expansions, but no new additions, production capacity is forecast to increase to about 280 KTA by 2001, and demand to increase to 195 KTA, so that Canada will remain dependent on a significant level of exports to maintain economic utilization of capacity.

4.4 North American Producers

4.4.1 USA

Producers of both solid PS and EPS resins in the USA are concentrated mainly in the North East and Mid-West regions. The only exceptions are plants in California (American Polystyrene, and Dow), Louisiana (Fina), and Virginia and Alabama (both NOVA). The complete list of producers and their capacities, effective January, 1998 or more recently where available, is shown in Tables 6 and 7 below:

Table 6 US Producers of Solid PS

Company	Location	Capacity (KTA)
American Polymers	Worcester, MA	34
American Polystyrene	Torrance, CA	14
BASF	Joliet, IL	342
Chevron/Phillips	Marietta, OH	349
Dart	Owensboro, KY	48
Deltech	Troy, OH	68
Dow	Gales Ferry, CT	73
	Ironton, OH	63
	Joliet, IL	127
	Midland, MI	136
	Pevely, MO	77
	Torrance, CA	113
Fina	Carville, LA	465
GE/Huntsman	Selkirk, NY	50
Kama	Hazleton, PA	34
NOVA	Belpre, OH	220
	Chesapeake, VA	180
	Decatur, AL	180
	Joliet, IL	105
	Springfield, MA	140

[Source: based on data from C E H, Marketing Research Report , “Polystyrene”, April, 1998, and other documents in the public domain]

Table 7 US Producers of EPS

Company	Location	Capacity (KTA)
BASF	South Brunswick, NJ	136
Huntsman	Peru,IL	116
NOVA	Beaver Valley, PA	185
	Painesville, OH	35
Radnor Holdings	Fort Worth, TX	54

[Source: based on data from C E H, Marketing Research Report , “Polystyrene”, April, 1998, and other documents in the public domain]

4.4.2 Canada

PS production in Canada is mainly located in the historic petrochemical centers in eastern Canada, i.e. Ontario and Quebec. Only the Dow PS plant in Sarnia, and the NOVA EPS plant in Pointe-aux-Trembles are close to world-scale. The full, but short, list of producers and their capacities, effective January, 1998 or more recently where available, is shown in Table 8 below:

Table 8 Canadian PS Producers

Company	Location	Capacity (KTA)
Dow	Sarnia, ON	140 (1)
Huntsman	Mansonville, PQ	16 (2)
NOVA	Pointe-aux-Trembles, PQ	60 (1)
Plasti-Fab	Crossfield, AB	8 (2)
Styrochem	Baie d’Urfe, PQ	17 (2)

[Source: based on data from C E H, Marketing Research Report , “Polystyrene”, April, 1998]

Notes: (1) Solid PS (2) EPS

4.4.3 Western North America

There are only three PS producers in western North America as defined in Section 4.1.4, and these are summarized in Table 9 below:

Table 9 Western North American PS Producers

Company	Location	Capacity (KTA)
American Polystyrene	Torrance, CA	14 (1)
Dow	Torrance, CA	113 (1)
Plasti-Fab	Crossfield, AB	8 (2)

[Source: based on data from C E H, Marketing Research Report , “Polystyrene”, April, 1998]
Notes: (1) Solid PS (2) EPS

4.4.4 Mexico

In Mexico, all the PS plants, except the BASF facility for production of solid PS, are small even by PS standards. Table 10 lists the producers and their capacities, effective January, 1998.

Table 10 Mexican PS Producers

Company	Location	Capacity (KTA)
BASF	Altamira	143 (1)
Industrial Ebro Quimex	Tizayuca	2 (1)
Mario Orozco Obregon	Leon	1 (1)
Monquimica	Monterrey	1
Poliestireno	Apizaco	30 (1)
Polimeros de Mexico	Cuatitlan	32 (1) ; 2 (2)
Polioles	Altamira	24 (2)
	Santa Clara	12 (2)
Resirene	Coatzacoalcos	41 (1)
	Xicotzingo	28 (1)

[Source: C E H, Marketing Research Report , “Polystyrene”, April, 1998]
Notes: (1) solid PS (2) EPS

4.5 Processes used for PS Production in North America

Solid PS was first produced commercially by Dow in 1938. The original polymers were crystal PS and were produced by the batch suspension process. However, rubber modified products (impact PS) were developed in the 1950’s in order to improve polymer mechanical properties, using continuous mass (or bulk, or solution) technology, and this process has largely superseded the suspension process for the manufacture of both crystal and impact PS products.

The suspension process has two advantages over mass technology:

- it can be used when initial plant capacity requirements are low, and a small number of reactors are installed, with subsequent addition of reactors as demand builds, and capacity needs to be increased
- grade changes can be made from batch to batch, eliminating the "twilight" production generated as process changes are made in the continuous mass process.

Suspension technology is used exclusively in the production of EPS, and to a large degree for the production of low volume, special application grades, such as high heat and high molecular weight grades.

4.5.1 Suspension Process

In the production of crystal PS by this process, SM and demineralised water are charged to the stirred reactor vessel, along with the polymerization catalyst (usually benzoyl peroxide) and suspension agent (calcium phosphate). The reactor is fitted with an external heating/cooling jacket. The polymerization is initiated by a combination of steam heating applied via the reactor jacket, and the catalyst. The agitation speed and concentration of the suspension agent govern the ultimate PS bead size by maintaining the dispersion of the SM in the water phase during polymerization. The catalyst concentration and the time/temperature cycle determine the polymer properties such as molecular weight and softening point.

At the end of the heating cycle, the reactor contents are water-cooled, and discharged to buffer vessels for subsequent water removal by centrifuge, and flash-, and/or fluid-bed-drying to remove the remaining moisture. The full-range beads are then graded by sieving to remove oversize, and fine beads, and the middle-cut fed to an extruder where property-modifying additives can be incorporated and the final product obtained in the form of strand-cut granules for bulk or packaged shipping.

A similar process is used to produce EPS beads with the following differences:

- when the product is to be used for steam-molded insulation block, or shaped protective packaging, the bead size requirement is larger than for crystal PS, and the suspension agent used is frequently a mix of naturally-occurring products. For foam cup application, the EPS bead size requirement is similar to crystal PS, and calcium phosphate can be used.
- the blowing agent, most often pentane, is incorporated under pressure in the reactor, at the end of the polymerization cycle.

- The full-range beads are graded not only to remove oversize and fine beads, but also to produce several narrow-range fractions which are subsequently coated with proprietary additive systems, before packaging in sealed drums for shipping.

4.5.2 Mass Process

This process polymerizes SM, sometimes using a diluent (often EB at 5 to 10%) in a series of stirred reactors, followed by removal of unreacted SM and any added diluent. Finally, the molten polymer is extruded and strand-cut into granules for sale. For the production of impact grades, polybutadiene rubber is dissolved in SM and fed to the pre-polymerisation reactor.

The important features of the continuous mass polymerisation process are:

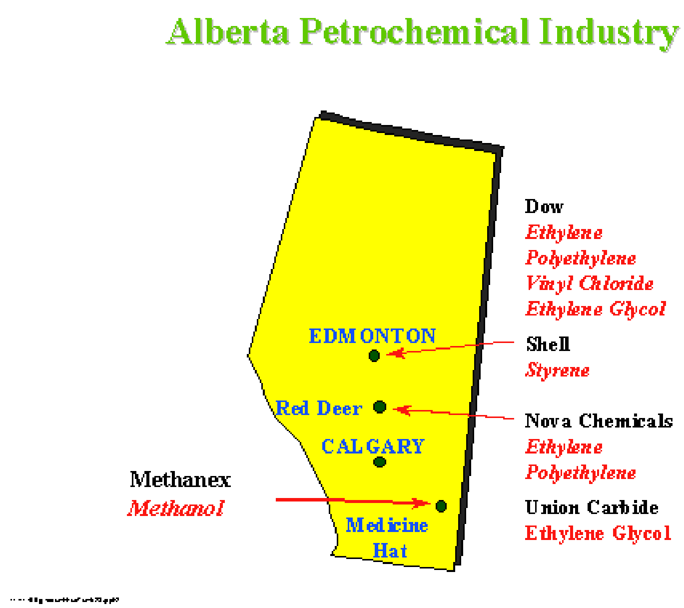
- the design of the reactors including method of heat removal, mixing characteristics, and the number of reactors used in series
- the devolatilisation technology used to remove traces of unreacted SM in order to meet stringent food and medical end-use specifications
- the technology used to prepare the polybutadiene rubber for copolymerisation to produce impact grades of PS, including grinding the baled rubber and dissolving it in SM for feed to the pre-polymerisation reactor.

There are many technologies in commercial use in North America, often designed specifically by or for the individual producer, but they all have the main components outlined above. Reactor design is probably the area which varies most from plant to plant.

Mass polymerization is now the predominant technology used in large-volume, minimal grade production facilities for both impact and crystal types of PS.

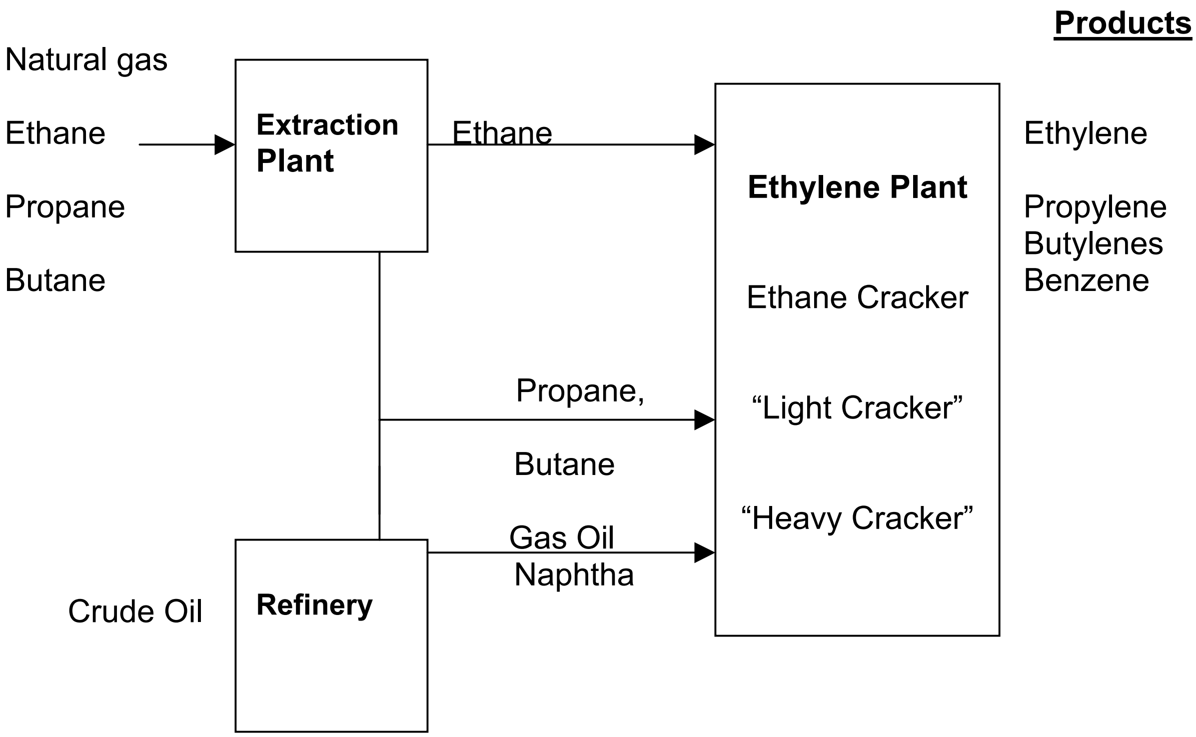
5.0 EXISTING ALBERTA FACILITIES

Figure 8 Alberta Petrochemical Industry



In the mid-1970's, the development of world-scale petrochemical facilities, based exclusively on ethane as feedstock, was commenced. The ethane was extracted from natural gas leaving the province in the major export pipelines. Leading this development were Dow, Dome (now part of BP Amoco), and Alberta Gas Trunk Lines (AGTL, now NOVA Chemicals). The Alberta government was also an important part of this development, through its policies to diversify the provincial economy, add value to Alberta resources within the province, and ensure that ethane would be available for the industry.

Figure 9 Production of Petrochemical "Building Blocks"



The viability of the Alberta ethylene and derivatives developments was premised on:

- **The availability of a secure long-term supply of ethane that has an alternative value of fuel when left in natural gas.**

- **A sufficiently low cost of ethane to offset the extra transportation costs to export markets for the Alberta producer.**

- **The ability to use ethane as feedstock, thereby minimizing the cost penalty for transporting co-products to locations where they can be upgraded to useful products.**

- **World-scale ethane extraction, ethylene, and ethylene derivative plants, resulting in unit production costs competitive with other regions.**

- **Lower capital and operating costs compared to plants using heavier feedstocks.**

- **An ability to access global markets with competitive cost derivatives, based on the above production cost advantages.**

As a result of the above factors, the ethylene-based petrochemical industry in Alberta has flourished.

World production of ethylene, and consumption of its derivatives is currently about 86 to 88 million tonnes per annum, and has grown by about 4.5% annually over the last 20 years. Growth is expected to continue at this rate for the foreseeable future. In the meantime, the investment in Alberta noted above, has resulted in the province's share of global ethylene production rising from 1.3% in 1980 to 2.7% in 1997. With the projects completed since 1997, and those currently in construction, this share will rise to about 4.2% by the end of the year 2000.

Alberta's petrochemical industry is now the second largest manufacturing industry in the province.

5.1 Strengths and Weaknesses

The rapid growth of the Alberta petrochemical industry since the mid-1970's was the result of the creation of a positive environment by the provincial government in its desire to diversify the provincial economy, and significantly increase the value added to resources in the province. This positive climate has been fostered by:

- a stable political environment,
- a competitive tax regime,
- a healthy fiscal policy, and
- an efficient regulatory process.

As a result, petrochemical investments by major global chemical companies are continuing into the early years of this century.

Additional strengths which have been developed over the last twenty years, and assist in attracting investment to the province, include:

- a well-educated and skilled operating and maintenance workforce with a positive attitude,
- a continuous supply of well-qualified graduates,
- attractive legal and insurance costs,
- trade arrangements (FTA and NAFTA).

The most important factors that negatively influence investment in Alberta are related to its geography:

- the distance from, and therefore transportation cost to, markets,
- the small size of the manufacturing base.

The two elements that have been most important in attracting and sustaining petrochemical investment in Alberta, and offsetting the negative geographic influences, are feedstock availability and price. Because feedstock cost represents around 65% of the full cost (including capital), and as high as 85% of the cash cost, of production, a reduction of its competitiveness cannot be offset by any other component or combination of components of the cost of production.

Table 11 Alberta Derivative Plants - 2002

Owner	Plant	Start Up	Location	Production Capacity (KTA)	Ethylene Consumption (KTA)
NOVA	PE-1	1984	Joffre	575	545
	PE-2	2001	Joffre	360	340
DOW	PE-84	1984	Ft. Sask	580	545
	PE-98	1998	Ft. Sask	300	285
	EG	1979	Ft. Sask	360	220
	EDC/VCM	1979	Ft. Sask	730	320
Hoechst Celanese	VA		Edmonton	80	26
UCC	PE	2000	Prentiss	590	635
	EG	1984	Prentiss	365	220
A&OG	EG	1994	Prentiss	400	240
ATP	LDPE/EVA		Edmonton	145	150
BPAmoco	Alpha Olefins	2001	Joffre	245	250
Shell Chem	EG	2000	Scotford	400	240
	Styrene	1984	Scotford	450	120
COCHIN PIPELINE EXPORTS TO SARNIA					90
TOTAL ETHYLENE DEMAND FROM ALBERTA SOURCES					**4216**

In Alberta today, the only PS manufactured is by Plasti-Fab Ltd. division of PFB Corporation at Crossfield, and is in the form of EPS. This 8 KTA of EPS is consumed by Plasti-Fab to manufacture expanded polystyrene insulation and structural components.

Dow Chemical also consumes PS in Fort Saskatchewan, and uses approximately 4 KTA of PS to produce foam sheet for consumption as meat trays, egg cartons, dinnerware, fast-food packaging and foamed insulation board.

6.0 ALBERTA PS PLANT AND PROCESS SELECTION CRITERIA

6.1 Key Plant Criteria

In order to take advantage of the Alberta benefits, minimize the geographic disadvantage, and maximize the probability of a PS investment in the province, the plant selection should meet the following criteria:

- be constructed at one of the existing petrochemical manufacturing sites, i.e. Joffre, Fort Saskatchewan, or Scotford, in order to take advantage of synergies at such a "brownfield" site
- be "world-scale", i.e. in the case of solid PS be at least 100 KTA, and in the case of EPS be at least 50 KTA, and in both cases have the ability to be expanded to at least double these capacities
- be designed to produce a minimum grade range of commodity products
- in the case of solid PS, have the capability to produce both crystal and impact products
- have access to a long-term, secure supply of SM
- have the ability to purchase SM at a price which reflects a sharing of the savings to the SM producer of avoiding the shipping and handling costs incurred in distributing SM itself, or shares with the SM producer the margin between the cash cost of SM and the PS netback to the location
- have access to cost-competitive fuel and utilities

6.2 Process Selection

For the solid PS plant with a capacity of at least 100 KTA, and a minimum array of commodity products, **the preferred process is mass polymerization**, which allows for production of both crystal and impact PS. The actual technology employed, particularly in the polymerisation section, would be dictated by the manufacturing company which elects to invest.

Suspension technology which could be used, on a dedicated basis, to produce crystal PS requirements, is more capital intensive, and incurs higher variable operating, labour, and maintenance costs, and is thus less economically attractive.

A minimum 50 KTA **EPS facility would employ the suspension process**. It is not recommended that crystal PS and EPS be produced in the same reactors, and finishing units, because of the potential for cross-contamination of suspension system, blowing agent, and bead size.

Comparative economics for US Gulf Coast (USGC) located facilities for the production of crystal PS and impact PS using the mass process, and for EPS using the suspension process, are shown in Table 12 below, expressed in 1998 US$.

Table 12 Comparison of PS Production Economics,

USGC in 1998 US$

	Crystal	**Impact**	**EPS**
Process	Mass	Mass	Suspn.
Reactor Type	Plug Flow	Plug Flow	Stirred
Product	General Purpose	High Impact	Expandable Beads
Capacity (KTA)	50	50	30
Capital Cost (M$) (1)	33	33	33
Production Costs (c/lb)			
- Net Raw Matls. (2)	36.2	37.1	35.9
- Utilities (3)	0.4	0.5	1.3
- Direct Fixed Costs (4)	1.6	1.6	2.7
- Allocated Fixed Costs (5)	1.2	1.2	2.0
Total Cash Cost	39.4	40.4	41.9
Depreciation	2.9	2.9	4.9
ROI (10%)	2.9	2.9	4.9
Cash Cost + ROI	45.4	46.2	51.7
CMAI Pricing (US c/lb)	38.5 – 42.0	40.0 – 44.0	44.0 – 48.0

[Source: based on Chem Systems PERP Report on Polystyrene, May, 1997. Inflated to 1998 $]

Notes: (1) Includes ISBL, OSBL and Other project costs.
(2) Includes feedstock (SM), catalyst, chemicals and additives
(3) Electricity, steam, cooling water, process water
(4) Labour, supervision, maintenance
(5) Plant overheads, property taxes and insurance, HSE costs

7.0 ECONOMIC EVALUATION

An economic model was developed to evaluate the profitability of constructing and operating a crystal/impact PS plant in Alberta, using local SM as feedstock, and shipping the product to consumers in Alberta, North America and Asia. The model takes input as project costs (capital and expense), inflation, operating rates, feedstock and product prices, logistics costs, corporate tax rate and GDP deflator; and generates the Net Present Value (NPV) of a stream of real cash flows at a given discount rate, as well as the project earning power (EP). All data is in Canadian $ unless otherwise stated.

Table 13 Major Project Premises

Product Type	**Crystal/Impact PS**
PS Capacity	**100 KTA**
Initial Capex (2000$)	**$90 million**
Project Expense	**4% of Initial Capex**
Location	**Alberta brownsite**
Start of Capital Spending	**2003**
Start of Production	**2006**
Years of Operation	**20**

Table 14 Economic Factors

Expenditure Phasing	**2003 2004 2005 2006**	**8% 27% 50% 15%**
Canadian Exchange Rate (USc/$CDN)	**2003,2004 2005-2007 2008-2010 2010+**	**0.69 0.70 0.71 0.72**
GDP Deflator	**2003-2026**	**2% per Year**
CCA@ 30% declining balance		
Depreciation Rate		**5% Per Year**

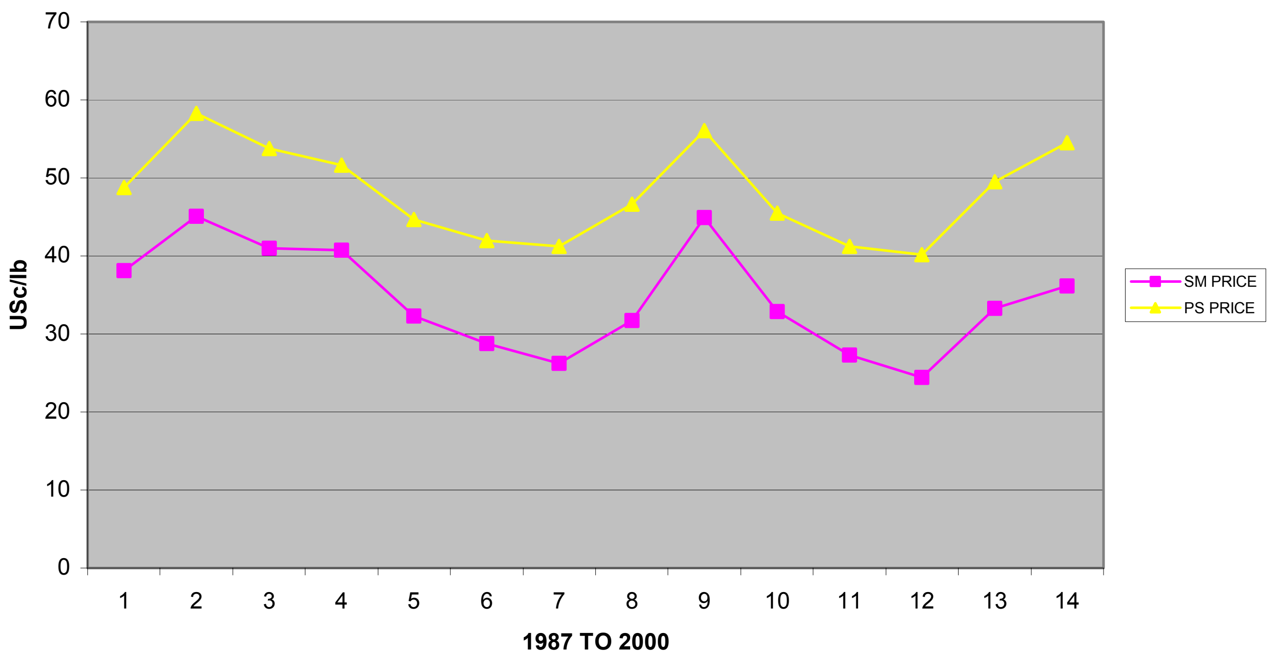
Table 15 Logistics Costs from Alberta

	US c/lb
Styrene to Chicago	1.25
Styrene to Taiwan	2.61
Styrene to California	2.85
PS to Chicago	1.09
PS to Taiwan	2.64
PS to California	2.50

7.1 Styrene/Polystyrene Price Relationship

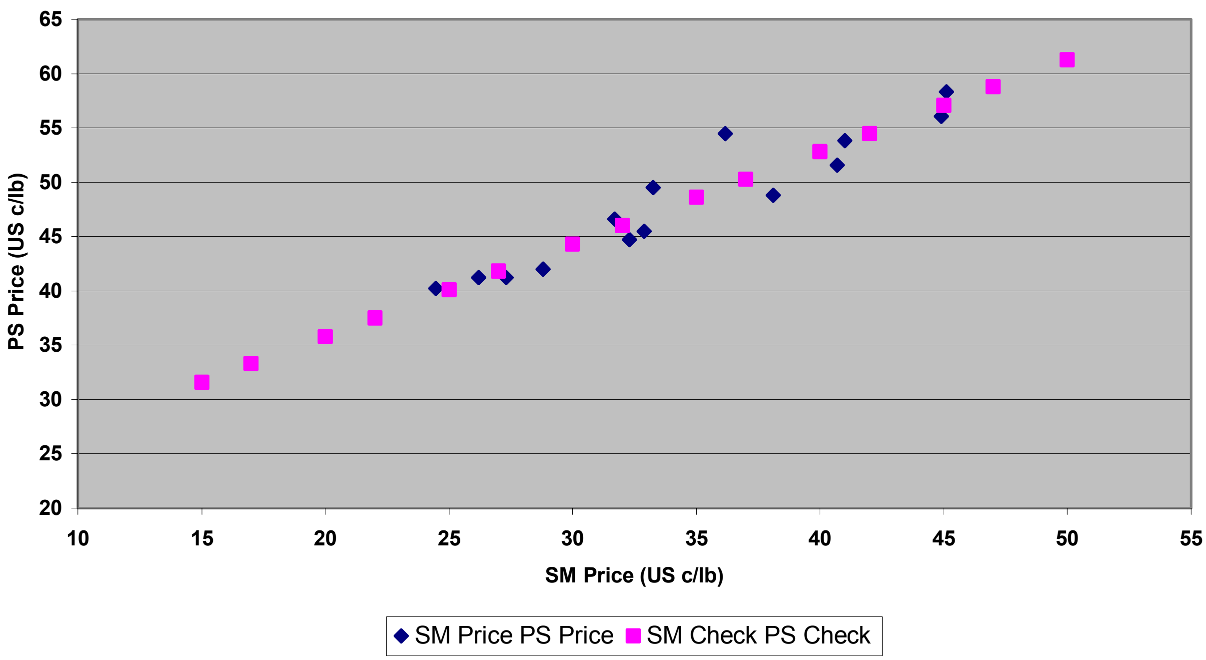
As can be noted in the Figure 10 below, USGC market prices for SM and crystal PS were charted for the years 1987 to 2000. Product prices were taken from historical listings of the Monomers Market Report by CMAI, and represent monthly contract prices. For SM, prices represent discounted prices in the USA, FOB plant gate, and for PS, prices reflect delivered high heat grade.

Figure 10 SM & PS Prices



In general, Figure 10 above shows that when the SM price falls, the PS price also falls, but to a lesser degree; and, when SM prices rise, those of PS also rise, but somewhat less. It would appear that price volatility for PS is less than for SM, most likely because of interpolymer competition from polyolefins. As SM prices rise, PS price increases are restricted by prevailing prices of polyethylene, polypropylene, PET and other competing polymers. When SM prices recede, PS value added is permitted to increase, depending on prices of competitive materials.

Figure 11 PS Price vs. SM Price



The result of such market place mechanics is shown in Figure 11 above, where the PS price is plotted versus the SM price. The black points on the curve represent those taken from historical data, while the pink points result from a linear equation representing a regression analysis of historical points.

The equation that best represents the relationship of PS price to that of SM over a broad range of SM prices is shown in Table 16.

Table 16 Styrene/Polystyrene Price Relationship

Styrene Price (US c/lb.)	PS Price (US c/lb.)
X	Y = 18.85 + 0.85 SM Price

7.2 Base Case Assumptions and Results

The base case assumed that the major premises of Table 13 apply and that all future real cash flows were discounted at 8% per annum. An additional assumption called for all transportation savings accruing to SCCL, as a result of supplying SM to a nearby location, to be transferred to the PS producer as a discount off the SM market price. SCCL can avoid transporting SM to distant customers in favour of shipping to a PS producer nearby, and still attract North American SM pricing. The logistics savings were comprised of rail and marine costs for a slate of product delivered as follows:

- 40% to Chicago
- 40% to Taiwan
- 20% to California

This base case also assumed that the destinations for the PS were as follows:

- 40% Chicago
- 40% Taiwan (via Vancouver)
- 20% California

Production economic assumptions, based on a USGC price for SM of 30 US c/lb, were as shown in Table 17 below.

Table 17 2006 Process Economics Summary (USc/lb)

Raw Materials	
Styrene (30.0 US c/lb X 1.015 lb SM/lb PS)	30.45
Other	1.89
Total Raw Materials	**32.34**
Utilities	0.38
Variable Costs	**32.72**
Fixed Costs	2.56
Cash Costs	**35.28**
Polystyrene Average Netback	41.47
Cash Cost Margin	**6.19**
Variable Cost Margin	**8.75**

Source: Public Documents and Chem Systems Process Economics

The results of this base case were an attractive NPV of $54 million, and a strong earning power of 16.1%.

The base case results were as follows:

- **NPV_8 = $54 million**
- **Earning Power = 16.1 %**

7.3 Project Sensitivities

Several project inputs were varied to understand the impact upon project profitability. Those factors with the greatest impact upon the outcome were as follows:

- Polystyrene Price
- Capital Cost
- Exchange Rate
- Apparent Corporate Tax Rate
- Sharing of Styrene Logistics Savings
- Further Styrene Discounts

7.3.1 Polystyrene Price

The PS market price was increased and decreased by 1 US c/lb and 2 US c/lb throughout the twenty-year project life. These changes were imposed on the model, without changing the SM price, and were thus input without using the SM/PS price relationship set out in Table 16. Results of the PS market price changes were as follows:

A PS price increase of 1 US c/lb yields an NPV_8 of $68.3 M and an EP of 17.9%. A price increase of 2 US c/lb yields an NPV_8 of $82.6 M and an EP of 19.6%.

A PS price reduction of 1 US c/lb gives an NPV_8 of $39.7M and an EP of 14.2%, while a further reduction to 2 US c/lb gives an NPV_8 of $25.4M and an EP of 12.1%.

7.3.2 Capital Costs

The capital cost of the project was increased and decreased by $10 million (2000$), with results as follows:

Capex $100 million: NPV_8 decreases to $47.2M, and EP to 14.6%

Capex $80 million: NPV_8 increases to $60.8M and EP to 17.9%

7.3.3 Exchange Rate

In the base case, the exchange rate of the Canadian dollar in US funds is as shown in Table 14. Sensitivities to this case were imposed as follows:

- Freeze the exchange rate at 67 US cents per Canadian dollar throughout. This sensitivity enhances the project to an NPV_8 of $62.0 M, and an E P of 17.0%.

- Advance the exchange rate to 69 US cents in 2003 and 2004, 72 US cents from 2005 to 2007, and 75 US cents per Canadian dollar from 2008 forward. This sensitivity reduces project profitability to an NPV_8 of $49.0M and an E P of 15.4%.

7.3.4 Corporate Tax Rate

Whereas an apparent corporate tax rate of 38% was chosen for the base case, a sensitivity of plus or minus 5% impacts the project profitability as follows:

Increasing corporate tax to 43% reduces NPV_8 to $47.9M and EP to 15.4%.

Reducing corporate tax to 33% increases NPV_8 to \$60.1 M, and EP to 16.7%.

7.3.5 Shared Transportation Cost Savings

In the base case, all SM transportation cost savings captured since this feedstock would be consumed close to the SCCL SM facility, were allocated as a reduced SM price to the PS plant owner. Should negotiations yield a sharing of these savings with SCCL, a reduction in the PS project profitability would result, as follows:

Transportation savings shared with SCCL in a ratio of 75% to the PS plant owner/ 25% to SCCL reduces the NPV_8 to \$46.4M and the E P to 15.1%.

7.3.6 Discounts in Styrene Price

Although the cash cost margin and variable cost margin are relatively strong for the base case project, any significant discount in the styrene feedstock cost greatly improves PS project profitability. Should negotiations between the PS plant owner and SCCL result in discounts of one or two cents per pound of SM in addition to the savings generated by supplying SM to an Alberta PS destination, the impacts are as follows:

An additional discount of 1.0 US c/lb. of SM increases the NPV_8 to \$68.3 M, and the E P to 17.9%.

An additional discount of 2.0 US c/lb. of SM increases the NPV_8 to \$82.6 M, and the E P to 19.6%.

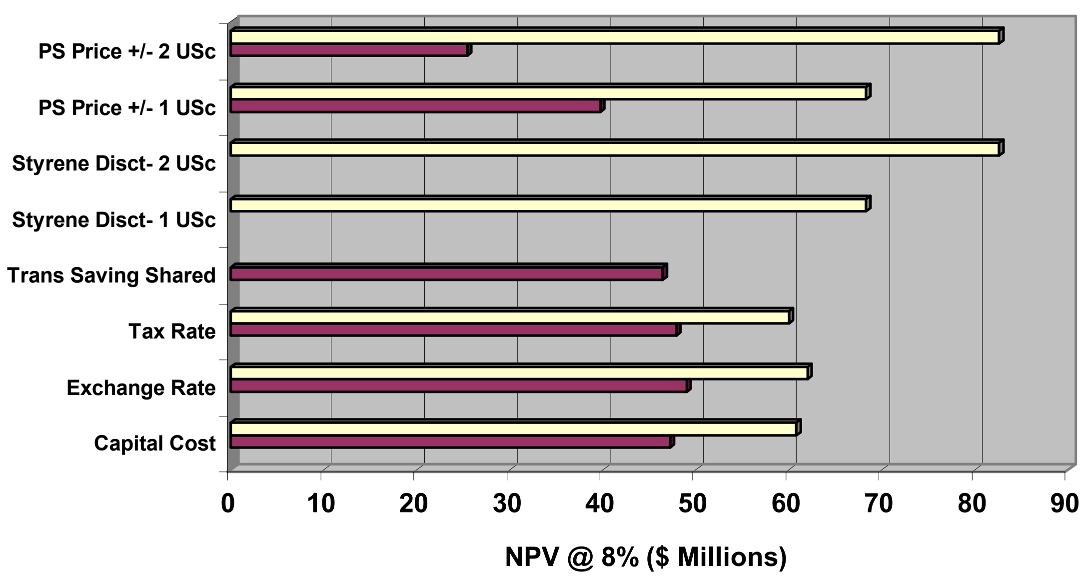
The basis for such discounts is discussed in a later section of this report. It is not the intent of the authors to suggest that such discounts could be achieved, but to indicate the importance of the discounts to a PS project proposed for Alberta. However, it should be noted that, for long term offtakes in the order of 100KTA of product, such discounts are not unusual in the North American marketplace.

7.3.7 Project Sensitivity Summary

The project profitability summaries shown in Figures 12 and 13 indicate that, for the subject PS project to merit further detailed economic evaluation and eventual process design and construction, SM price discounts may not be necessary. As well, capital costs must be maintained at or near those on the USGC, and all CCA's must be written off immediately against existing income streams, i.e., the PS plant owner will require current operating assets in Alberta.

Figure 12 Project Sensitivities

Figure 13 Project Sensitivities



7.4 The Cash Cost SM Example

In its annual reports on Petroleum and Petrochemical Economics (PPE), Chem Systems tabulates and compares the costs of manufacturing and shipping key petrochemicals from representative production locations throughout the world. As part of this report, Chem Systems reviews the costs of production of SM, and includes the SCCL facility at Scotford, Alberta.

The PPE report compares production costs of SM at Scotford with those in the Middle East, the USGC, Western Europe, and other major production locations. Chem Systems uses its knowledge of SM production economics and specific plant information to determine plant costs and the cost competitiveness of known plants.

In the Chem Systems PPE Report, dated April, 1999, the production costs for styrene are tabulated and compared. In this report, the SCCL plant in Scotford is shown to have the lowest cash costs of production of all plants reviewed.

The authors of this PS report have taken some assumptions from the Chem System report and have combined these assumptions with our historical petrochemical database of SM, benzene and ethylene prices, to yield an approximation of Scotford SM cash costs over the past fourteen years. The SM cash costs took into account the cost advantages of purchasing feedstocks (benzene and ethylene) in Alberta, compared to those on the USGC. Such advantages relate only to alternate use, and discount the cost of ethylene and benzene on the USGC by the cost of transporting both from Alberta to the USGC markets.

This effort allowed us to input Alberta “cash cost” SM to the economic model of PS production, and to identify the profitability of using such SM as feedstock for PS throughout the project life. Transportation savings of shipping styrene locally are not included in this evaluation. The results are as follows:

Cash Cost Styrene to the PS Project

NPV_8 = $154 million

Real Earning Power = 27%

This is not to suggest that the PS producer would provide feedstock to the PS project at cash cost, but it serves to put a maximum on PS project profitability…this is as good as it gets!

8.0 POTENTIAL PARTNERS/PRODUCERS

The top three PS producers in the world are:

- Dow Chemical
- NOVA
- BASF

Of these producers, Dow and NOVA are the most active members of the Alberta petrochemicals group of companies, and are the most natural candidates for a PS project in Alberta.

In Alberta, Dow currently produces ethylene, polyethylene, ethylene glycol and EDC /VCM at its complex in Fort Saskatchewan, and via the proposed purchase of Union Carbide assets, may soon produce ethylene, polyethylene and ethylene glycol in Joffre and Prentiss. Dow produces 140 KTA of crystal and impact PS in Sarnia, Ontario, and imports approximately 4 KTA of this product to Fort Saskatchewan to produce foam sheet for consumption in meat trays, egg cartons, dinnerware and fast-food packaging, and foam board for insulation.

At its large complex at Joffre, NOVA produces ethylene and polyethylene. It produces 60 KTA of crystal PS in Point-aux-Trembles, Quebec.

PFB Corporation, Plasti-Fab Ltd. division, produces 8 KTA of EPS at its Crossfield, Alberta, facility.

SCCL produces SM and ethylene glycol at its Scotford, Alberta location. The SM facilities have been in service since 1984, while the glycol plant started up in July of this year. Internationally, Shell Chemicals Limited recently exited the PS business by selling its solid and expandable PS businesses to NOVA in January, 2000. It thus makes sense that SCCL would not be interested in a direct investment in an Alberta-based PS project.

Whereas Dow Chemical and NOVA would be the most logical candidates for a PS venture in Alberta, BASF may also be interested in such a plant, should the project prove to be advantaged. Plasti-Fab may wish to consider participation, if they wish to significantly expand their facility, and to make their plant a part of a larger complex to reduce overheads.

SCCL would be the main supplier of SM feedstock, and thus would significantly impact the profitability of the project. Negotiations for SM supply to an Alberta PS project in the region of 100KTA could lead to SM discounts, backed by agreements to share profits in the PS business, above a determined profit level. In this manner, SCCL would not be directly be investing in the PS project, but would be taking part in PS profits in “good times”.

9.0 CONCLUSIONS

9.1 General Project Evaluation

Since the base case project profitability is quite attractive, the authors have determined that an Alberta-based PS project could be successful, assuming that the project utilizes modern, efficient process technology, is world scale (at least 100KTA), is located on a brownfield site, and has access to competitive styrene feedstock with discounts of one or two US c/lb (not unusual in the North American marketplace), in addition to the SM transportation savings. Such additional SM discounts place project profitability in a range of 18-20% earning power. Even without additional styrene discounts the project has an earning power of 16% and warrants a hearing at any corporate board on its own merits. Such real, after tax earning powers establish such a project as attractive and worthy of further evaluation by candidate production companies.

9.2 Dow Chemical Alberta PS Requirements

As mentioned in Section 8.0, Dow Chemical Canada brings approximately 4 KTA of PS from Sarnia to Fort Saskatchewan, for the production of foam sheet and board, for local consumption.

It would make sense that a producer of PS in Alberta would be successful in negotiating with Dow for the supply of PS to the foam PS facility. Assuming that the PS plant would be close to Dow's existing complex, almost all of the transportation costs of bringing PS from Sarnia to Fort Saskatchewan would be saved, and could be shared between the PS manufacturer and Dow. The transportation savings are probably approximately 400 K$/year, and the PS producer's negotiated share of this saving would enhance the PS project.

9.3 Profit Sharing With Shell Chemicals Canada Ltd.

SCCL is the only SM manufacturer in Alberta, and is critical to any PS project mounted in the province. Just as SCCL would be the only supplier of SM to the project, the project would most likely become the largest single site consumer of SCCL's Scotford SM. With such potential synergy available, any PS producer would consider including Shell in an SM supply agreement that gives Shell access to PS profits above a set level, throughout the life of the long term supply agreement.

SCCL must see the profitability of the PS venture as important to its long term success in the global SM business.

9.4 Styrene/Polystyrene Partnership

In all economic evaluation efforts to this point, the authors have assumed that the SM for the PS project could be diverted from SCCL's current product destinations, and that, with sufficient notice, such could be accomplished for an end-use close to the Scotford plant.

For whatever reason, should this not be possible or desirable, there might be a case that would require SCCL to expand its existing facility to provide the additional 100 KTA of SM. The authors assume, for use in calculations, that such an addition would cost SCCL approximately $50 million in capex.

Such a requirement would truly result in a partnership, wherein SCCL would invest approximately $50 million in additional SM production facilities at Scotford, while the new PS company would invest approximately $90 million in the new PS plant and ancillaries. Thus, the total investment commitment will be $140 million.

In Section 7.4, the economics of a cash cost case was investigated, wherein the cash cost of SM produced from alternate value benzene and ethylene in Alberta, i.e. USGC price less transportation cost from Alberta to the USGC, was input to the PS project, with all profits of such a case being assumed by the PS business. If we take the same alternate value benzene and ethylene as feed for the required SM expansion (100KTA of SM), and again use such advantaged SM to produce 100 KTA of PS, the profitability of such a combined venture would have to be spread over the two projects. As in the cash cost case for PS alone, the transportation savings of styrene in the base case are not included in this evaluation.

Using the same model inputs as for the base case of the PS project, but with the capital cost now at $140 million ($90 million for PS and $50 million for SM), the SM transportation costs removed, and cash cost for the 100KTA of SM required for the project, the economic results are as follows:

Evaluation of Combined SM Expansion and PS Projects

NPV_8 = $120 million

Real Earning Power = 19%

Assuming that such economic results meet the criteria of the parties, then the benefit from the combined projects could be shared between the parties in proportion to the capital expended by each, and be backed by a long term agreement to supply and to purchase 100KTA of SM.

The mechanism for sharing the benefit on the project would be in the form of an SM price in such long-term agreement equal to the cash cost of SM plus SCCL's capital-based share of the margin between the PS netback to the PS producer, and the SM cash cost.

Such an expansion of styrene by Shell requires approximately 80 KTA of additional benzene as feed. The authors are aware that the additional supply of Alberta-based benzene might be a constraint to such an expansion.

This opportunity would appear sufficiently attractive as to warrant further discussions with SCCL.

10.0 PROFILES OF PRINCIPALS

10.1 Harry Blair

Mr. Blair's background and industry experience relevant to this project include:

- Actively participating in the development and management of a major Canadian petrochemical company at the executive level, and of a major oil company as a senior manager
- Establishing new business lines within a major Canadian and global petrochemical company, including significant manufacturing, global marketing and distribution operations
- Heading the polypropylene business for Shell Canada Limited
- Managing development of feedstock strategies for the expansion of the petrochemicals company referred to above
- Developing international relationships for expanding Canadian operations and product marketing in the USA and Asia
- Negotiating long term supply contracts for feedstocks and utilities valued at several billions of dollars

10.2 Neil Bradford

As principal of NB Consultants (NBC), Mr. Bradford will provide support to Harry Blair Consulting (HBC) in this study.
Mr. Bradford established NB Consulting in 1998 on his retirement from Shell Chemicals Canada Ltd. In this capacity he has successfully carried out several client studies/ projects for government agencies, petrochemical companies and associations. He is an accomplished professional in the petrochemicals business in Canada, with North American and global perspectives. Strengths include business economic analysis, strategic planning, feedstock and utilities supply negotiation, and petrochemical manufacturing operations.

Mr. Bradford has 32+ years experience with a major international petrochemical company, in the UK and Canada, and has extensive knowledge of the industry in Canada and the USA.
Some of Mr. Bradford's accomplishments include:

- Negotiating and renewing long-term petrochemical feedstock and utilities supply contracts, in Eastern and Western Canada, with values in the $175 million to $2 billion range.
- Representing his company on a multi-company group charged with monitoring/controlling ethylene cost of service, and optimising supply arrangements from the major Alberta ethylene producer.

- Generating detailed forecasts of supply/demand and cost advantages for petrochemical feedstocks (ethane, ethylene, propylene, aromatics) in Canada, for use in justification of investment proposals, resulting in the strategic decision to construct a major $350 million project in Alberta.

11.0 LIST OF TABLES

12.0 LIST OF FIGURES

13.0 REFERENCES

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