# POLYCARBONATE PRODUCTION FROM BPA AND DPC

IN THE UNITED STATES

PREVIEW

PREMIUM EDITION

BY INTRATEC SOLUTIONS LLC

# COMMODITY PRODUCTION COSTS

REPORTS COLLECTION

BY INTRATEC SOLUTIONS LLC

VOLUME

# POLYCARBONATE PRODUCTION

ISSUE

# POLYCARBONATE PRODUCTION FROM BPA AND DPC

COUNTRY OF ANALYSIS

UNITED STATES

SERIES

PREVIEW

EDITION

PREMIUM

DEVELOPED BY

INTRATEC SOLUTIONS LLC

REPORT CODE

INTRATEC-ICC-PREV-200-B-PREM-USA

This report is part of a series of reports prepared by Intratec approaching the production costs of commodities spanning a diverse range of industries: Oil & Energy; Fertilizers & Gases; Olefins & Derivatives; Aromatics & Derivatives; Alcohols & Organic Acids; Polymers; Inorganic Chemicals; Food & Nutrition; Metals & Mining; and Pharmaceuticals.

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# IMPORTANT NOTICE

This document is a preview report provided by Intratec, showcasing the full structure of a cost analysis related to Polycarbonate Production from BPA and DPC.

To protect proprietary data, numerical values have been replaced with "X" placeholders and charts have been intentionally blurred. Nonetheless, this preview faithfully reflects the structure and depth of the commercial report, including the types of tables, charts, and descriptions presented.

Intratec offers multiple preview and sample reports to support purchasing decisions. Therefore, free trials are not available.

An up-to-date commercial report about this technology can be purchased at www.intratec.us/icc/200-B.

# Abstract

This report presents a manufacturing cost analysis of Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate.  The process examined is a typical melt process.  This process is based on the transesterification reaction of BPA with diphenyl carbonate to produce Polycarbonate. During the reaction, phenol is removed and obtained as a by-product.

This report examines the capital costs of a Polycarbonate plant and the continuing operating costs associated with the plant.  The analysis assumes a plant based in the United States with a capacity of 0.000 mt of Polycarbonate per year and includes:

* Polycarbonate plant capital cost details, including ISBL, OSBL and Contingency; owner's cost; working capital; and costs incurred during industrial plant commissioning and start-up.
* Operating cost, broken down by variable costs (raw materials, utilities); fixed costs (maintenance, operating labor, plant overhead, property taxes and insurance); and depreciation.
* Raw materials consumption, products generation, and labor requirements.
* Polycarbonate production process information including block flow diagram (BFD), process flow diagram (PFD) and description of industrial site installations.

This report was developed based essentially on the following reference(s):

"Polycarbonates", Ullmann's Encyclopedia of Industrial Chemistry, 7th edition

Keywords: Thermoplastic Polymer, Polycondensation, SABIC, Mitsubishi, Asahi

# Revision Control

The following pages present a history of revisions and main changes made in the last updates of the report “Polycarbonate Production from BPA and DPC.” The changes in each revision are classified according to the types presented below:

* Fix: errors correction in a released report (e.g., typos, wrong descriptions/economic figures).
* Update: changes made by the Intratec team in the release of a new Series of reports (e.g., change of a technical parameter published in a more recent patent).
* Improvement: structural changes common to all Intratec Commodity Production Costs reports aiming to improve the accuracy of presented estimates or reader’s comprehension of reports.

## Report Revision History – Series XXXX

| | |
|---|---|
| Rev. 0 | Original |

# Report Changes History – Previous Series

The list below presents the main changes made in the "Polycarbonate Production from BPA and DPC" report released in previous Series.

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# Preamble

## Understanding Intratec Commodity Production Costs

### Reports Organization

Intratec Commodity Production Costs is a set of best-in-class professional reports that can be understood as an encyclopedia approaching plant capital and operating costs of commodities' manufacturing processes. The Intratec Commodity Production Costs reports are organized in a particular fashion, as shown in the diagram presented on the next page. The diagram shows that the reports are organized in Quarterly Series according to the period of the economic analysis presented. Every new quarter Intratec reviews the entire Series – new reports are developed, and existing reports are updated. After the release of a new Series, the reports from previous Series stop being sold. Currently, each Series includes more than 800 reports.

The reports Series are divided into Volumes, with each Volume focusing on processes for manufacturing a specific commodity. The entire Series approaches more than 250 commodities (Volumes), spanning a diverse range of industries. Each Volume, in turn, is composed of Issues, each one targeting a specific industrial process to produce the respective commodity.

Each report is identified by a unique code, containing the information on Series, Volume, Issue, Edition, and Location used as basis in the economic analysis. An example of code is shown below.

INTRATEC-ICC-Q122-001-A-PREM-USA

- Country USA - Country assumed in the economic analysis
- Premium Edition - Code corresponding to the report edition
- Issue A - Manufacturing process approached in the report
- Volume 001 - Target commodity produced
- Series Q122 - Quarter/year assumed in the economic analysis
- Product ICC - Intratec Commodity Production Costs reports

# HOW INTRATEC COMMODITY PRODUCTION COSTS REPORTS ARE ORGANIZED

## SERIES

Every quarter all reports are updated and the entire series is reviewed. Intratec does not sell reports from previous series.

## VOLUMES

Set of issues (reports) targeting the production of a specific commodity.

## ISSUES

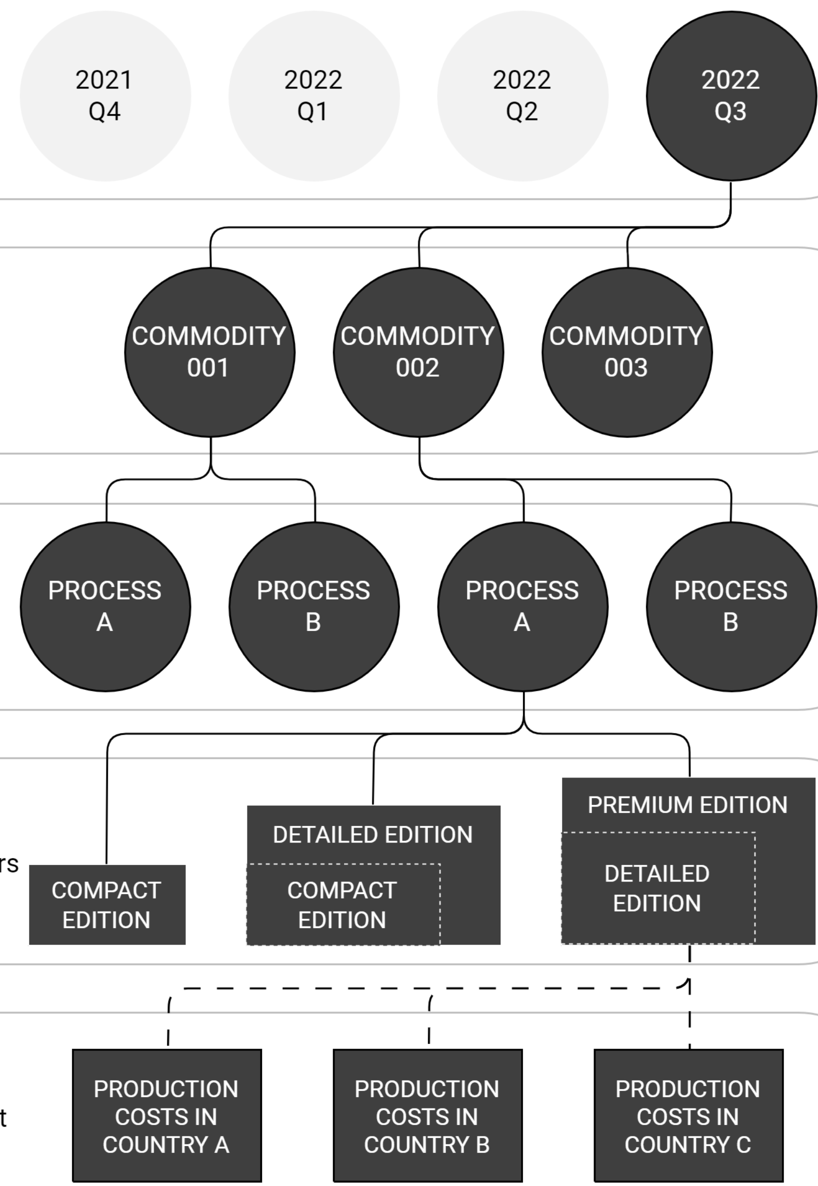
Each issue approaches an industrial process for the production of the commodity.

## EDITIONS

Each issue is offered in three editions designed to attend customers interested in different levels of depth.

## COMPANION REPORTS

Companion reports, each one with economic analysis of a different country, are offered as add-ons to the Premium Edition.



## Editions Available

Aiming to attend customers with a wide range of needs, each Issue is offered within three different Editions with increasing levels of depth, as detailed below.

* **Compact Edition.** This Edition describes the industrial plant, including main process units and site infrastructure, and presents an independent economic analysis through summarized figures. It is perfect for those looking for a brief overview of the process, and an objective understanding of its economics.

* **Detailed Edition.** This Edition includes, besides all the content from the Compact Edition, additional assumptions and further details related to the economic analysis. This Edition is suggested for the readers interested in a more comprehensive analysis and concerned in understanding each assumption used in the development of the Issue.

* **Premium Edition.** This is the most popular and detailed Edition offered for a given Issue. It includes everything from the Detailed Edition plus additional economic and technical information about the process, which enables readers to go deeper in their analysis. This version is an excellent starting point for readers interested in checking different scenarios and developing more in-depth studies.

For more information about the content of each Edition, the reader is referred to the Table of Contents of each report.

## Intratec Commodity Production Costs Support

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**Interested in Technical Support?**

For information about the terms of technical support (available only in the Premium Edition), customers are referred to: https://intrat.ec/icc-report-support.

To understand how to upgrade to Premium Edition of this report, the reader is referred to: https://intrat.ec/icc-report-upgrade.

## Companion Reports

Intratec also offers, as an add-on for the Premium Edition, companion reports with economic data for the manufacturing process assuming other plant locations. More specifically, each companion report has a detailed economic analysis with the same structure presented in the main report, considering a plant in a different country.

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The countries covered by the Commodity Costs of Production reports are: United States, Australia, Austria, Belgium, Brazil, Canada, China, Czech Republic, Finland, France, Germany, Greece, Hungary, India, Indonesia, Italy, Japan, Malaysia, Mexico, Netherlands, Norway, Philippines, Poland, Portugal, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, and United Kingdom.

# About This Report

## Identification

This report, "INTRATEC-ICC-PREV-200-B-PREM-USA," corresponds to the Issue B of a set of reports which is part of Volume 200, released in the Series XXXX. More specifically, this report refers to:

| Item | Code | Description |
|---|---|---|
| Product | ICC | Intratec Commodity Production Costs |
| Series | XXXX | Quarter (XX) and year (XXXX) used as basis for the economic analysis |
| Volume | 200 | Polycarbonate |
| Issue | B | Polycarbonate Production from BPA and DPC |
| Edition | PREM | Corresponds to the Premium Edition of the report |
| Country | USA | The economic analysis presented in this report is based on a plant located in the United States |

## How to Use

The main purpose of this report is to assist readers in conducting a preliminary economic evaluation of the industrial process presented. It serves as a valuable tool for studies such as screening investment options, evaluating emerging processes, assessing economic feasibility, cost estimation double-checking, and more.

Readers should keep in mind the limitations of this report, as both the technical data and economic assessment are subject to certain constraints.

**Technical Data.** The preliminary design of the process is based on fast techniques that rely on reduced design efforts. The goal of such preliminary design is exclusively to represent the process in sufficient detail for supporting capital and operating costs estimation within the accuracy expected: class 4 budgetary estimates. Therefore, the technical data presented must not be confused with an actual conceptual process design and must not be used as such.

**Economic Assessment.** The report presents an economic assessment for the period XXXX, assuming an industrial facility based in the United States. This means that capital and operating costs estimates presented are based on several general assumptions (e.g., average market figures for raw materials, chemicals and utilities prices, labor costs, taxes, and duties), believed to suitably portray local conditions for the period of analysis informed, on a country-level basis. Accordingly, the economic assessment provided in this report is not meant to fit any specific industrial venture, which would involve a wealth of specific data and assumptions not herein considered.

Finally, it is important to highlight mistakes to avoid when using Intratec Commodity Production Costs reports:

* The reports are not process design packages nor engineering documentation of any kind.
* The reports are not based on surveys, interviews, or confidential information.
* The reports are not based on any kind of confidential information.
* The content of our reports is not tailored to customers' demands. On the contrary, all reports share the same structure (types of graphs, tables, and descriptions) and depth of content, and the content itself is the result of Intratec development methodology.
* Intratec reports are not consulting services, though users are free to use the information in conjunction with their own data or hire consulting firms for specialized analyses.

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# Acronyms & Abbreviations

| | |
|---|---|
| AACE | Association for the Advancement of Cost Engineering |
| BEQ | bare equipment |
| BFD | block flow diagram |
| Btu | British thermal unit |
| CAPEX | capital expenditures |
| CW | circulating cooling water |
| EPC | engineering procurement and construction |
| FEED | front-end engineering design |
| ft | feet |
| G&A | general and administrative |
| HAZOP | hazard and operability study |
| HP | high pressure |
| IC index | Intratec plant construction cost index |
| ISBL | inside battery limits |
| IT | information technology |
| kWh | kilowatt-hour |
| LP | low pressure |
| m3 | cubic meter |
| MM | million |
| MP | medium pressure |

| | |
|---|---|
| mt | metric ton |
| NASA | National Aeronautics and Space Administration |
| Nm3 | normal cubic meter |
| OC | owner's cost |
| Op. | operator |
| OPEX | operational expenditures |
| OSBL | outside battery limits |
| PFD | process flow diagram |
| R&D | research and development |
| RF | refrigeration fluid |
| ROCE | return on capital employed |
| ST | steam |
| Sup. | supervisor |
| t | ton |
| TFC | total fixed capital |
| TPC | total process capital |
| TRL | technology readiness level |
| wt | weight |
| yr | year |

# Chapter 1

# Executive Summary

## About Polycarbonate

Polycarbonate (a.k.a. PC) is a thermoplastic polymer/resin, derived from diphenyl carbonate, phosgene and bisphenol A. The polymer is easily molded and thermoformed, and for that, along with its properties, polycarbonates are among the most used plastics in industry. Polycarbonate has a high impact and dielectric strength, heat resistance, it is noncorrosive and extremely dimensionally stable. Depending on the grade, the resulting material is translucent, so PC has been used as a substitute to glass, although it is not its primary use, due to PC being more expensive than polymethyl methacrylate (acrylic). The main uses of PC are in the construction industry and as engineering materials. Because of their unusual properties (e.g. toughness, clarity), Polycarbonates figure among the top engineering thermoplastics.

PC is usually transported and stored as sheets. It is not flammable and very little toxic, although it should be kept away from heat sources, since it might decompose into bisphenol A, a potential carcinogen, and others volatile organic compounds (VOCs) dangerous to the environment and to humans.

Polycarbonate is used mainly in electrical/electronics (optical information storage media: lamp sockets, multiple contact strips, relay parts, power plugs, safety switches, housings, digital disks); building and construction (roofings, fences, windows, paints); automobiles (headlight and taillight covers,bullet-proof glass, reflectors, fan and radiator grills); office equipment (covers, keyboards, casings); plastic products (bottles, cups, furniture); food packaging (cellophane); and other applications (eye lenses, industrial fibers, recycled polymer alloys).

# Polycarbonate Production Process

The present analysis approaches Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate.

The process under analysis comprises 3 major sections: (1) Polymerization; (2) Phenol Purification; and (3) Polycarbonate Pelletizing.

Polymerization. Diphenyl carbonate melt, bisphenol A and sodium dihydrogen phosphite are mixed and heated to form a melt. The stream is fed to a oligomerization step, where low molecular weight oligomers are generated. The oligomers are directed to more severe conditions, then polymerization is completed in two CSTR operating in series. Polymerization is interrupted by addition of n-butyl tosylate, which deactivates the catalyst. Phenol and other by-products are continuously removed from the process.

Phenol Purification. The by-products are sent to a distillation column. Phenol is withdrawn from overhead and exported to nearby facility.

Pelletizing. The polymer melt is filtered, and a mix of additives is added. The mixture is homogenized and pelletized. Finally, the pellets are conveyed to homogenization system and fed to the packing system.

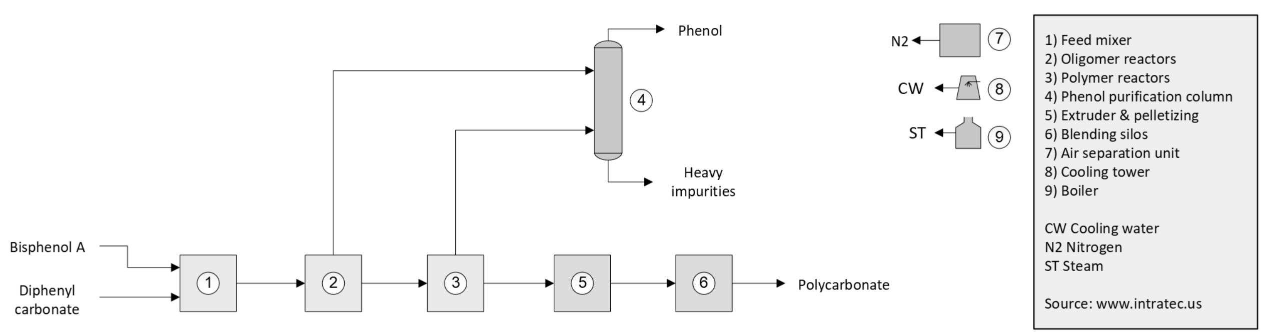



Figure 1.1 Process Schematic Diagram

# Economic Analysis

Table 1.1 provides a summary of the Polycarbonate production cost related to the process described in the report, based on a 0.000 mt/yr plant. Also, it presents some remarks about the key aspects surrounding the economic analysis performed.

Table 1.1 Polycarbonate Production Cost Summary

| Polycarbonate Production from BPA and DPC | | | |
|---|---|---|---|
| Plant location | United States | **Capital investment summary** | **MM USD** |
| Period of analysis | XXXX (IC Index: XXX) | Fixed capital | XXX |
| Nominal capacity (mt/yr) | 0.000 | Working capital | XXX |
| Operating rate (h/yr) | XXX (XXX XXX%) | Additional capital | XXX |
| Annual production (mt/yr) | XXX | **Total capital investment** | **XXX** |

| Description | USD/mt | MM USD/yr | % |
|---|---|---|---|
| Net raw materials cost | XXX | XXX | XX |
| Net utilities cost | XXX | XXX | XX |
| **Operating variable costs** | **XXX** | **XXX** | **XX** |
| Operating fixed costs | XXX | XXX | XX |
| **Operating cash cost** | **XXX** | **XXX** | **XX** |
| Depreciation | XXX | XXX | XX |
| **Total operating cost** | **XXX** | **XXX** | **XX** |
| Corporate overhead | XXX | XXX | XX |
| ROCE | XXX | XXX | XX |
| **Product value** | **XXX** | | **XX** |

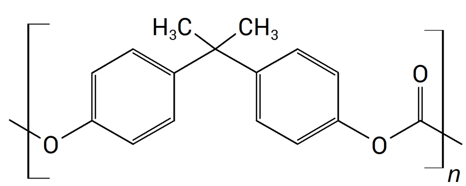
Table 1.1 shows the impact of variable costs in the product value — it represents approximately XX % of the product value. Regarding the capital investment it is worth mentioning that, in order to fulfill the infrastructure requirements assumed in the present analysis, OSBL investment represents about XX% of the Polycarbonate plant cost.

# Chapter 2

# About Polycarbonate

Polycarbonate (a.k.a. PC) is a thermoplastic polymer/resin, derived from diphenyl carbonate, phosgene and bisphenol A. The polymer is easily molded and thermoformed, and for that, along with its properties, polycarbonates are among the most used plastics in industry. Polycarbonate has a high impact and dielectric strength, heat resistance, it is noncorrosive and extremely dimensionally stable. Depending on the grade, the resulting material is translucent, so PC has been used as a substitute to glass, although it is not its primary use, due to PC being more expensive than polymethyl methacrylate (acrylic). The main uses of PC are in the construction industry and as engineering materials. Because of their unusual properties (e.g. toughness, clarity), Polycarbonates figure among the top engineering thermoplastics.

The structure of Polycarbonate is presented below:




Bisphenol A Polycarbonate

Figure 2.1 Polycarbonate

These polymers are produced on an industrial scale via two main routes, where one is based on the reaction of an aromatic diol with phosgene in an amine-catalyzed interfacial condensation reaction, and the other involves a base-catalyzed transesterification of a bisphenol with a monomeric carbonate. Commercially, the most important polycarbonate is the one made from bisphenol A, referred to as bisphenol A polycarbonate BPA-PC.

PC is usually transported and stored as sheets. It is not flammable and very little toxic, although it should be kept away from heat sources, since it might decompose into bisphenol A, a potential carcinogen, and others volatile organic compounds (VOCs) dangerous to the environment and to humans.

## Commercial Forms & Applications

The uses and applications of Polycarbonate may vary according to its specification. The main forms of Polycarbonate are general purpose grade; flame retardant; anti-static; film grade (food packing); stress crack resistance; and bullet resistant.

Polycarbonate is used mainly in electrical/electronics (optical information storage media: lamp sockets, multiple contact strips, relay parts, power plugs, safety switches, housings, digital disks); building and construction (roofings, fences, windows, paints); automobiles (headlight and taillight covers,bullet-proof glass, reflectors, fan and radiator grills); office equipment (covers, keyboards, casings); plastic products (bottles, cups, furniture); food packaging (cellophane); and other applications (eye lenses, industrial fibers, recycled polymer alloys).

## Polycarbonate Production Routes

Polycarbonate is typically manufactured via the interfacial polymerization reaction of phosgene and bisphenol A. Other production processes include a non-phosgene process in which bisphenol A reacts with diphenyl carbonate (DPC). Production pathways may also differ by integrating bisphenol A or DPC production.

Figure 2.2 Polycarbonate Production Routes Diagram

Fig. 2.2 comprises a diagram showing different Polycarbonate production processes. This report is part of the Intratec Commodity Production Costs reports, focused on Polycarbonate manufacturing processes.

Intratec has also developed other reports focused on other Polycarbonate production processes. More information about such industrial processes are presented below.

## Issue A

It illustrates the Polycarbonate (PC) production from bisphenol A (BPA) and phosgene. In this process, BPA, dissolved in an aqueous solution, is reacted with phosgene, in an organic solution, at the interface of the two-phase mixture. The carbonate oligomers produced are then polycondensed to Polycarbonate resin. See reference:

* Intratec. XXXX. Polycarbonate Production from BPA and Phosgene, Report ICC-XXXX-200-A-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue A. Premium Edition. Available at: www.intratec.us/icc/200-A.

## Issue C

It illustrates the Isosorbide Polycarbonate production from glucose and ethylene oxide via a melt process. In this process, the Isosorbide Polycarbonate plant is integrated with a plant for isosorbide production from glucose and a plant for diphenyl carbonate production from ethylene oxide. The process uses a 70 wt% glucose-water syrup as raw material and generates ethylene glycol as by-product. See reference:

* Intratec. XXXX. Isosorbide Polycarbonate Production, Report ICC-XXXX-200-C-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue C. Premium Edition. Available at: www.intratec.us/icc/200-C.

## Issue D

It illustrates the Polycarbonate (PC) production from bisphenol A (BPA) and ethylene oxide. In this process, Polycarbonate production is based on the transesterification reaction of BPA with diphenyl carbonate (DPC). The Polycarbonate plant is integrated upstream with a plant for DPC production from ethylene oxide, which also generates ethylene glycol as a by-product. See reference:

* Intratec. XXXX. Polycarbonate Production from BPA and Ethylene Oxide, Report ICC-XXXX-200-D-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue D. Premium Edition. Available at: www.intratec.us/icc/200-D.

## Issue E

It illustrates the Polycarbonate (PC) production from phenol, acetone and phosgene. In this process, the Polycarbonate plant is integrated with a plant for bisphenol A (BPA) production from phenol and acetone. In this process, BPA is reacted with phosgene at the interface of a two-phase mixture. The carbonate oligomers produced are then polycondensed to Polycarbonate resin. See reference:

* Intratec. XXXX. Polycarbonate Production from Phenol & Acetone, Report ICC-XXXX-200-E-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue E. Premium Edition. Available at: www.intratec.us/icc/200-E.

## Issue F

It illustrates the Polycarbonate (PC) production from phenol, acetone, and methanol. In this process, the Polycarbonate plant is integrated with a plant for bisphenol A (BPA) production from phenol and acetone and a plant for diphenyl carbonate (DPC) production from phenol and methanol. The process is based on the transesterification reaction of BPA with diphenyl carbonate to produce Polycarbonate. See reference:

* Intratec. XXXX. Polycarbonate Production from Phenol, Acetone and Methanol, Report ICC-XXXX-200-F-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue F. Premium Edition. Available at: www.intratec.us/icc/200-F.

## Issue G

It illustrates the Polycarbonate (PC) production from bisphenol A (BPA), phenol and methanol. In this process, the Polycarbonate plant is integrated with a plant for diphenyl carbonate (DPC) production from phenol and methanol. The process is based on the transesterification reaction of BPA with diphenyl carbonate, followed by a polycondensation to produce Polycarbonate. See reference:

* Intratec. XXXX. Polycarbonate Production from BPA, Phenol and Methanol, Report ICC-XXXX-200-G-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue G. Premium Edition. Available at: www.intratec.us/icc/200-G.

## Issue H

It illustrates the Polycarbonate (PC) production from bisphenol A (BPA), phenol and phosgene. In this process, the Polycarbonate plant is integrated with a plant for diphenyl carbonate (DPC) production from phenol and phosgene. The process is based on the transesterification reaction of BPA with diphenyl carbonate, followed by a polycondensation to produce Polycarbonate. See reference:

* Intratec. XXXX. Polycarbonate Production from BPA, Phenol and Phosgene, Report ICC-XXXX-200-H-PREM-USA. In: Intratec Commodity Production Costs, Series XXXX. Volume 200 (Polycarbonate). Issue H. Premium Edition. Available at: www.intratec.us/icc/200-H.

# Chapter 3

# Process Overview

This chapter presents an overview of Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate.

More specifically, the current chapter approaches technical aspects of the Polycarbonate production process examined including technology maturity assessment and description of the products generated and the process inputs.

## Technology Maturity Assessment

The process technology under study was categorized according to its maturity. The technical maturity, while a measure of performance, reliability and operating experience associated with the technology being assessed, serves as an important input in the definition of assumptions that have a relevant impact on process economics (e.g., process contingency, project contingency, costs related to start-up inefficiencies and R&D, etc.).

The process technology maturity is defined by the Intratec team through a method adapted from the so-called Technology Readiness Level (TRL) method, developed by NASA, and nowadays used in a broad range of sectors/industries. There are nine TRLs, which describe the maturity of a technology, from basic technology research to system testing, launch and operations.

Originally intended to support decision-making over research and development activity, the nine technology readiness levels were divided into five major classes to portray the maturity level of chemical process technologies, from “concept” to “established technology.” Table 3.1 describes such five classes according to which the Intratec team classifies technologies being studied, as well as the TRLs included within each class.

Table 3.1 Process Technology Maturity Scale

| Technology Status | Description | Scale | TRL |
|---|---|---|---|
| Established (Outdated) | * Existing plants being shut down<br>* No longer adopted in new plants<br>* Obsolete technology | Commercial (at least 1 plant) | - |
| Established (In Use) | * 2+ commercial plants<br>* Proven technology (successful operations) | Commercial (2+ plants) | 9 |
| Emerging | * 1 commercial plant<br>* Basic data for commercial plant<br>* Performance validation<br>* Demonstration plant<br>* Prototype near or at planned operation system | Commercial (1 plant)<br>Demonstration | 7-8 |
| Embryonic | * Pilot-scale demonstration<br>* Engineering-scale models / prototypes<br>* Basic data for scale-up<br>* "Proof-of-Concept" validation<br>* Bench-scale demonstration<br>* Lab-scale technology definition<br>* Process modeling<br>* Analytical studies<br>* Active R&D | Pilot<br>Bench<br>Lab | 4-6<br>2-3 |
| Conceptual | * Unproven idea / proposal<br>* No analysis or testing<br>* Paper concept / studies | Concept<br>Idea | 1 |

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# Product(s) Description

The main product obtained in the process under analysis is melt BPA-based Polycarbonate. Phenol is also produced as a by-product of this process.

* Phenol

Hydroxybenzene, commonly known as phenol, is produced as a co-product of this production process during the transesterification reaction between bisphenol a and diphenyl carbonate. Highly pure phenol is obtained, at about 99 wt%, which can be sold to other chemical production facilities like bisphenol a and diphenyl carbonate manufacturers.

# Inputs Description

## Raw Material(s)

* Bisphenol A

Bisphenol A is a high volume production organic compound, synthesized from phenol and acetone. It has been produced in commercial since the 1950's and is mostly used in the production of polycarbonate plastic and epoxy resins. Nowadays its use in products with contact with food has been decreasing, mostly in the United States, due to a rising concern on the negative health effects it might cause.

For this analysis, it is assumed a high purity bisphenol-a, with a purity of 99 wt%.

* Diphenyl Carbonate (DPC)

Diphenyl Carbonate (also known as DPC and Phenyl Carbonate) is an acyclic carbonate ester, produced on commercial scale mainly from the phosgenation of phenol. This chemical is available in different forms: it can be delivered flaked in polyethylene sacks, or in the molten state in tank cars.

This phenol derivative is widely used in conjunction with bisphenol A in the manufacture of polycarbonates. DPC in molten state can be used as solvent for several substances such as cellulose ethers and esters, pharmaceutical and cosmetic preparations, polymer and salts, and as extractants, plasticizers, additive for cleansing agents, among other applications.

* Catalyst & Chemicals

This topic refers to several chemicals that are used in minor amounts in several process unit operations in this process.

In this process the melt polymerization is catalyzed by sodium dihydrogen phosphite and n-butyl tosylate is used to deactivate the catalyst in the end of the polymerization reaction.

Other chemicals comprising dyes, stabilizers, and lubricants are also mixed with the filtered polymer melt before extrusion.

The costs associated with the acquisition of this and other minor chemicals are taken into account under this item.

## Utilities

The utilities consumed in the process are cooling water, inert gas, steam and electricity.

**Process Highlights**

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# Chapter 4

# Industrial Site Configuration

This chapter presents the industrial site configuration for the Polycarbonate production process examined. In short, the information presented in this chapter is based on commonly utilized concepts related to the type of installations found within a typical industrial site. These concepts include:

* Process unit. Also known as inside battery units, these installations comprise all main units of the site required to modify the input stream and obtain the target output. These units are located Inside the Battery Limits (ISBL).

Infrastructure. Also known as outside battery units or offsite facilities, these installations do not directly enter into the modification of the process input stream. They are support buildings, auxiliary units used for providing and distributing utilities and storage facilities. These units are located Outside the Battery Limits (OSBL).

In order to make a better distinction between these types of installation, a diagram is presented in Figure 4.1. The diagram also provides an insightful overview of the industrial site as whole, and helps to clarify which raw materials and utilities are supplied to the process unit and which products and utilities are generated.

Figure 4.1 Industrial Site Configuration

# Chapter 5

# Process Unit

This chapter presents the process unit associated with the Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate. The process examined is a typical melt process.

Basically, the process unit is the core of an industrial site. Comprising the site's battery limits (ISBL), it may be complex and involve several pieces of equipment. In this context, to facilitate the understanding, the process unit related to the Polycarbonate manufacturing process under analysis is presented in the next pages through the use of a block flow diagram followed by a comprehensive description.

The information presented in this report was mainly based on:

"Polycarbonates", Ullmann's Encyclopedia of Industrial Chemistry, 7th edition

It is important to mention that some aspects of the Polycarbonate production process examined are either industrial secrets, not published in patents, or have changed, but were not reported in the literature at the time this report was developed. That being the case, the design herein presented is partially based on Intratec process synthesis knowledge such that there may be some differences between the industrial process actually employed and the Polycarbonate manufacturing process described in this study. Nevertheless, the design presented suitably represents the technology examined in sufficient detail to estimate the economics of the technology within the degree of accuracy expected from conceptual evaluations.

# Block Flow Diagram

In general, block flow diagrams consist of a series of blocks, representing unit operations or groups of equipment, connected by input and output streams. In fact, there are no strict standards according to which such diagrams are made.

To facilitate the presentation of the process unit under analysis, Intratec developed block flow diagrams according to some standards. The process areas represented correspond to a "functional unit." Basically, a "functional unit" is a significant step in the process in which a particular physico-chemical operation (i.e., distillation, reaction, evaporation) occurs. According to this definition, a given functional unit is not associated with a single piece of equipment, but rather with a group of equipment and ancillaries required to perform a particular operation.

The blocks representing process areas also show key technical parameters related to these areas, including: the highest operating temperature and pressure, representative material of construction, and other parameters.

As to the process streams represented, there is an indication of their phase. Also, such streams may provide a global material balance of the process, normalized by the mass flow rate of the product considered in the analysis. In other words, the number near each stream represents the ratio between its mass flow rate and the output flow rate of the product under analysis.

It is worth noting that areas having no significant impact on the economics of the process may not be included in the diagram. Similarly, some streams may also not be represented. Nevertheless, the diagram presented is still extremely useful in providing readers with an overall understanding of the process studied.

The following block flow diagram illustrates the functional units related to the process under analysis.

**Further Details**

For more information on how the process examined was divided into functional units, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

Figure 5.1 Block Flow Diagram — Polycarbonate Manufacturing Process

**Further Details**

For a more detailed diagram presenting pieces of equipment and more process streams, the reader is referred to "*Appendix I. Process Flow Diagram & Equipment List.*"

## Description

The Polycarbonate production process under analysis is briefly described below. For clarity, the description was divided according to the process areas indicated in the block flow diagram.

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# Chapter 6

# Site Infrastructure

This chapter describes the infrastructure requirements associated with the Polycarbonate production process examined. Basically, infrastructure requirements comprise the offsite facilities, or the units located Outside the Battery Limits (OSBL). The OSBL usually have a significant impact on the capital cost estimates associated with any new industry venture. This impact is largely dictated by, among other things: specific conditions where the industrial site will be erected; the level of integration the new site will have with nearby facilities or industrial complexes; and assurance and promptness in the supply of chemicals.

## Assumptions

The infrastructure requirements of the industrial site examined were defined according to the assumptions listed below.

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**Note**

According to the literature focused on the economic analysis of processes, the costs associated with waste treatment typically range from 0.5% to 5% of plant cost per year (See references M14, M15). However, since such costs may significantly vary from process to process and according to plant location, Intratec recommends a specific study for more accurate estimates.

## Description

The offsite facilities were divided into areas according to their type/function. These areas are listed in the following pages, as well as a description about the major equipment, systems and facilities included in each of them.

* Area 90 – Storage Installations

Figure 6.1 Area 90 – Storage Installations

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* Area 91 – Utilities Facilities

Figure 6.2 Area 91 – Utilities Facilities

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* Area 92 – Support & Auxiliary Buildings

Figure 6.3 Area 92 – Support & Auxiliary Buildings

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# Chapter 7

# Process Consumptions & Labor Requirements

This chapter presents the process requirements to operate an industrial site of the Polycarbonate production process examined. More specifically, the next pages provide key process indicators and the operators required to run the process equipment of the Polycarbonate manufacturing process examined (in accordance with the block flow diagram and the global material balance previously presented).

## Key Input & Output Figures

The following tables show key process indicators of the technology examined. In other words, these indicators reflect the raw materials consumption in Table 7.1 rates per metric ton of Polycarbonate.

Table 7.1 Raw Materials Consumption

| Raw Material | Quantity per metric ton of Product | Unit |
|---|---|---|
| XXXXXXXXX | XXX | XXX |
| XXXXXXXXX | XXX | XXX |

It should be noted that estimation of raw material requirements in the conceptual design phase is usually reasonably accurate, but tends to be somewhat understated compared to real operations. Losses from vessel vents, unscheduled equipment, inerting systems, physical property inaccuracies, startup, shutdown, and other process operations not typically addressed in this phase may increase raw materials consumption.

**Further Details**

For detailed figures regarding utilities consumption, reader is referred to "*Appendix A. Utilities Consumption Details.*"

## Labor Requirements

Table 7.2 presents the number of operators per shift required to run the equipment of the process examined, as well as the personnel per shift required to directly supervise the operating labor.

Table 7.2 Labor Requirements

| Personnel | Workers per Shift |
|---|---|
| Operators | XX |
| Supervisors | XX |

# Chapter 8

# Capital Costs Summary - United States

This chapter presents Polycarbonate plant capital costs associated with Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate, from design to industrial plant startup.

The costs that comprise the total Polycarbonate plant capital costs are grouped under three major costs:

* Fixed capital. Depreciable capital invested in the construction of the industrial plant and making it operational. It comprises the Polycarbonate plant cost and owner's cost, expenses required to make the plant operational (i.e., initial catalyst load in reactors, prepaid royalties, and miscellaneous costs).

* Working capital. Funds for getting the plant into operation and meeting subsequent obligations. It includes raw materials inventory, products inventory, in-process inventory, supplies and stores, accounts receivable and accounts payable.

* Additional capital requirements. One-time expenses related to bringing a process on stream during plant start-up. These expenses may be related to employee training, initial commercialization costs, operating inefficiencies, and unscheduled plant modifications.

Figure 8.1 illustrates the composition of total capital investment.

**Further Details**

For more information about how the capital costs were estimated, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

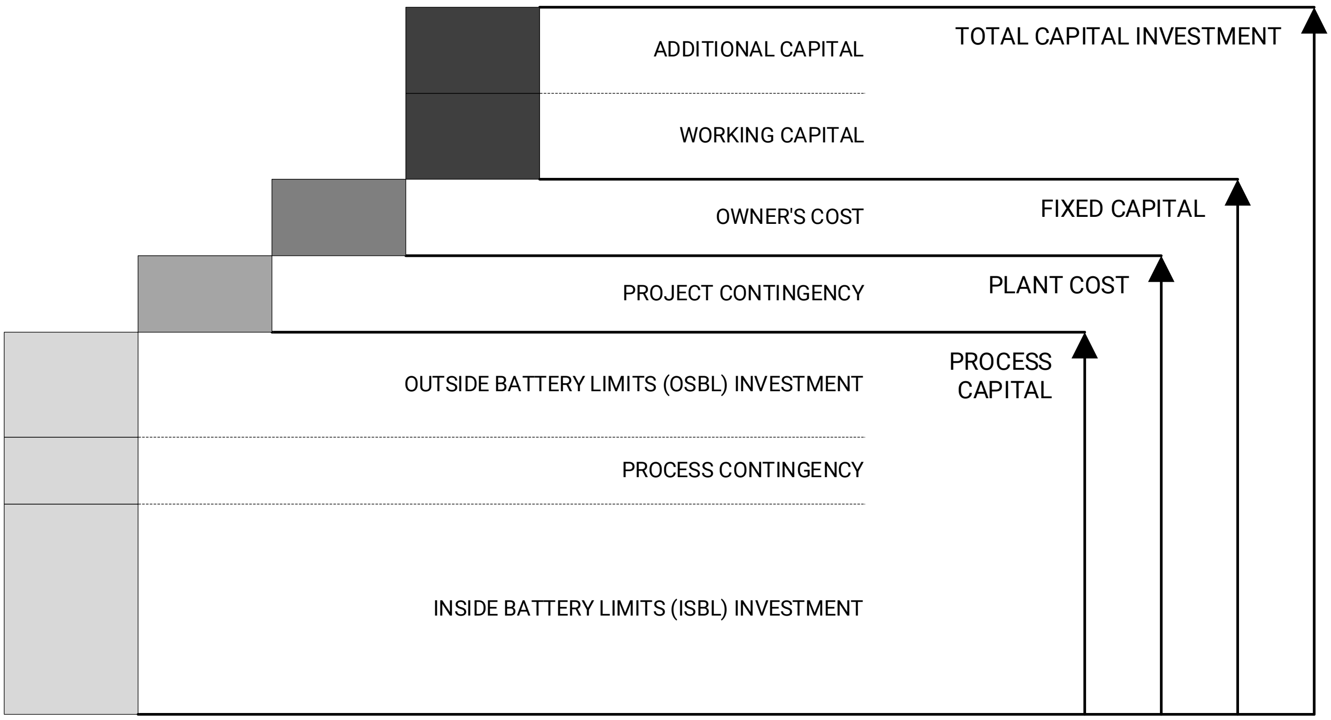


Figure 8.1 Capital Investment Composition

## Assumptions

The estimates included in this chapter are based on the following assumptions:

* Plant nominal capacity: **0.000 mt** of Polycarbonate per year
* Industrial plant location: **United States**
* Construction on a cleared, level site
* Period of analysis: XXXX
* IC Index-United States at the period of analysis: XXX

**Interested in Adjusting Construction Costs Over Time?**
Intratec Plant Construction Cost Indexes (IC Indexes) are multipliers monthly published by Intratec to scale capital costs from one time period to another. For more information, visit https://intrat.ec/industry-economics-worldwide.

# Total Capital Investment

Table 8.1 summarizes all major Polycarbonate plant capital costs that comprise the total capital investment, from the design and construction of an industrial site to plant startup.

Table 8.1 Capital Investment Summary

| Component | MM USD | % |
|---|---|---|
| Plant cost | XXX | XX |
| Owner's cost | XXX | XX |
| **Total fixed capital** | **XXX** | **XX** |
| Working capital | XXX | XX |
| Additional capital | XXX | XX |
| **Total capital investment** | **XXX** | **XX** |

Figure 8.2 presents a graphical representation of the total capital investment breakdown.

Figure 8.2 Capital Investment Summary

Further Details

For the breakdown of fixed capital, working capital and additional capital, reader is referred to "*Appendix C. Capital Investment Details*."

# Chapter 9

# Operating Costs Summary - United States

This chapter presents ongoing costs required for Polycarbonate (PC) production from bisphenol A (BPA) and diphenyl carbonate. Also referred to as operational expenditures (OPEX), these encompass costs associated with the plant operation and depreciation. In the current analysis, the operating cost was grouped under three major costs:

* Operating variable costs. Costs directly proportional to the actual operating rate of the industrial site. Such costs include raw materials and utilities (i.e., steam, electricity, fuel, and refrigeration).
* Operating fixed costs. Operating costs directly tied to the plant capacity, but which do not change with the operating level (i.e., operating labor, supervision labor, maintenance costs, plant overhead).
* Depreciation. Refers to the decrease in value of industrial assets with passage of time.

It should be kept in mind that the sum of operating fixed costs and operating variable costs is referred to as "cash cost." The sum of cash cost with depreciation, in turn, is referred to as "total operating cost."

Figure 9.1, on the next page, illustrates the composition of total operating cost.

**Further Details**

For more information about how the operating cost components were estimated, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

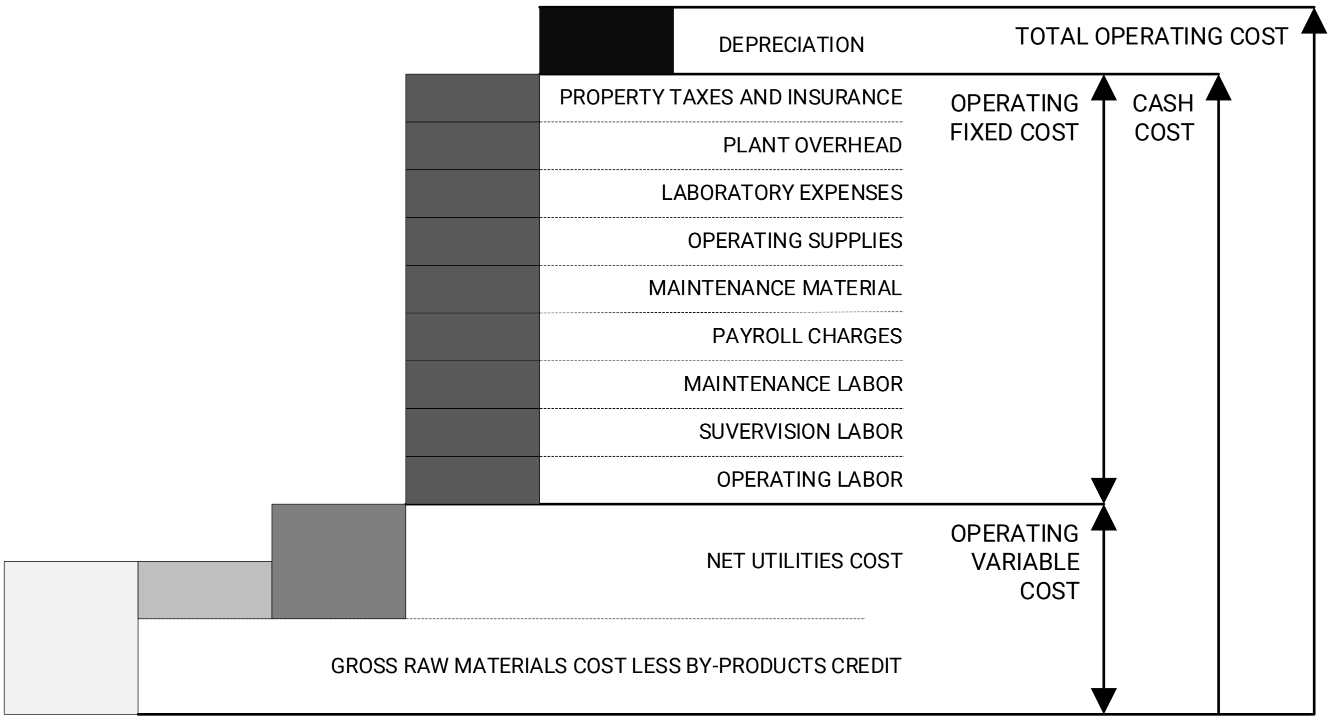


Figure 9.1 Operating Costs Composition

## Assumptions

The estimates included in this chapter are based on the following assumptions:

* Industrial plant location: **United States**
* Period of analysis: XXXX
* Plant nominal capacity: **0.000 mt** of Polycarbonate per year
* Plant operating rate (hours per year): XXX

The plant operating rate assumed leads to an annual throughput of XXX metric ton of Polycarbonate. It is important to mention that this rate does not represent any technological limitation; rather, it is an assumption based on usual industrial operating rates.

## Operating Variable Costs

Table 9.1 displays the operating variable costs.

Table 9.1 Operating Variable Costs

| Component | Quantity | Price | USD/mt | MM USD/yr | % |
|---|---|---|---|---|---|
| XXXXXXXXX | XXX XXX | XXX | XXX | XXX | XX |
| XXXXXXXXX | XXX XXX | XXX | XXX | XXX | XX |
| **Gross raw materials cost** | | | **XXX** | **XXX** | **XX** |
| **Net raw materials cost** | | | **XXX** | **XXX** | **XX** |
| Net utilities cost | | | XXX | XXX | XX |
| **Operating variable costs** | | | **XXX** | **XXX** | **XX** |

All costs presented in this table are derived from unit consumptions and pricing information.

## Total Operating Cost

Table 9.2 summarizes all operating cost by presenting its major components.

Table 9.2 Operating Costs Summary

| Component | USD/mt | MM USD/yr | % |
|---|---|---|---|
| Operating variable costs | XXX | XXX | XX |
| Operating fixed costs | XXX | XXX | XX |
| **Operating cash cost** | **XXX** | **XXX** | **XX** |
| Depreciation | XXX | XXX | XX |
| **Total operating cost** | **XXX** | **XXX** | **XX** |

Figure 9.2 presents a graphical representation of the operating cost breakdown.

Figure 9.2 Operating Costs Summary

**Further Details**

For the breakdown of utilities cost, operating fixed costs and depreciation, the reader is referred to "*Appendix D. Operating Costs Details.*"

# Chapter 10

# Product Value Summary - United States

This chapter presents the "Product Value," a term commonly used wherein all costs associated with the manufacture of a product are combined in order to provide a more consistent economic analysis. It includes operating cost (operating variable costs, operating fixed costs, and depreciation), as well as corporate overhead costs and an expected Return on Capital Employed (ROCE). Figure 10.1 illustrates the composition of the product value.

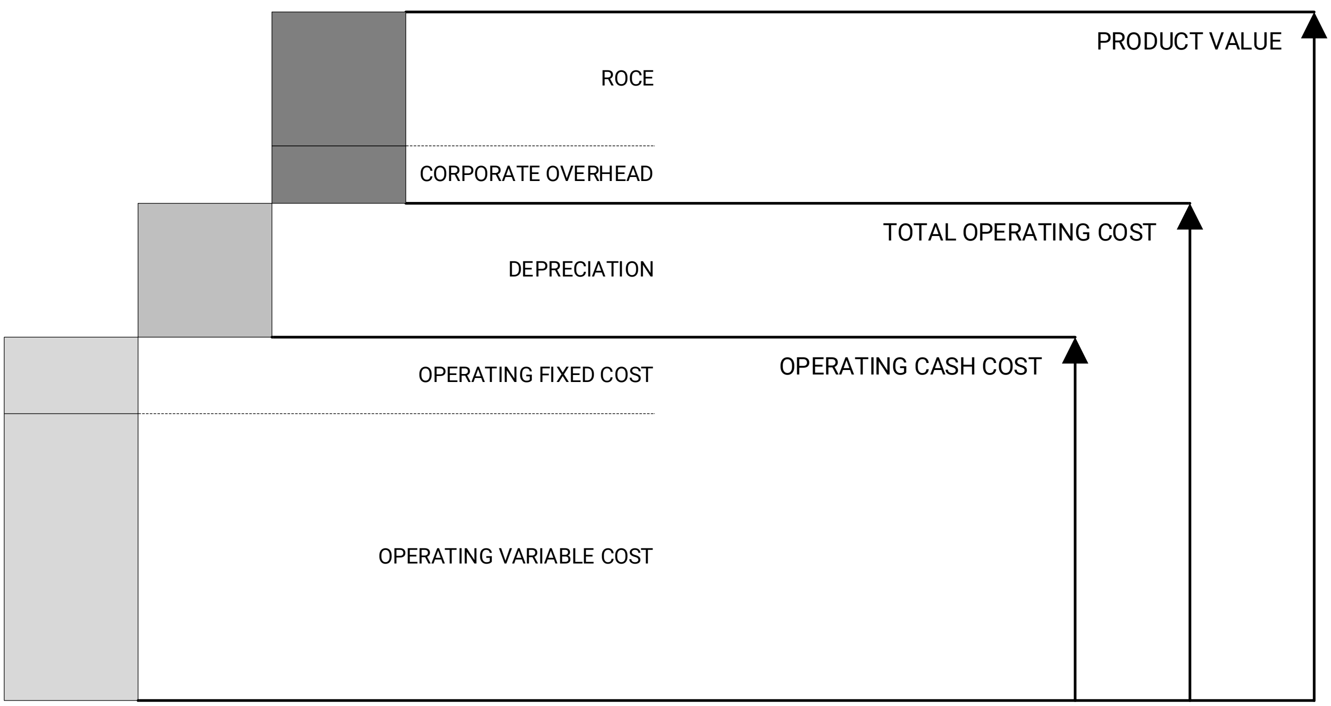


Figure 10.1 Product Value Composition

It is important to mention that product value should not be confused with product price. The product value should be seen as the minimum price for which the product could be sold, so that the plant owner can get the expected ROCE.

Table 10.1 summarizes all costs that comprise the product value in the process examined.

Table 10.1 Product Value Composition

| Component | USD/mt | MM USD/yr | % |
|---|---|---|---|
| Operating cash cost | XXX | XXX | XX |
| Depreciation | XXX | XXX | XX |
| **Total operating cost** | **XXX** | **XXX** | **XX** |
| Corporate overhead | XXX | XXX | XX |
| ROCE | XXX | XXX | XX |
| **Product value** | **XXX** | | **XX** |

Figure 10.2 shows the impact of each cost component on the product value.

Figure 10.2 Product Value Summary

# Chapter 11

# Production Costs Summary - United States

This chapter provides a summary of all Polycarbonate production costs related to the process described so far. Also, it presents some remarks about the key aspects surrounding the economic analysis.

## Polycarbonate Production Cost Datasheet

Table 11.1 condenses the analysis developed in this report.

## Economic Remarks

It should be noted that the risk taken into account in this analysis is limited to the technical risks associated with the process uncertainties or inherent risks associated with the venture's industry sector. Other venture risks, such as business environment, raw materials and product prices variations, change in government policy, shall be evaluated case by case, and are not taken into account here, since this is a general analysis.

It is also important to mention that product value must not be confused with product price. While the product value is calculated based on operating cost and expected ROCE, the product price is the actual value practiced in market transactions.

Table 11.1 Polycarbonate Production Cost Datasheet

## Polycarbonate Production from BPA and DPC

| | | | |
|---|---|---|---|
| Plant location | United States | **Capital investment summary** | **MM USD** |
| Period of analysis | XXXX (IC Index: XXX) | Fixed capital | XXX |
| Nominal capacity (mt/yr) | 0.000 | Working capital | XXX |
| Operating rate (h/yr) | XXX (XXX XXX%) | Additional capital | XXX |
| Annual production (mt/yr) | XXX | **Total capital investment** | **XXX** |

| Description | Quantity per mt | Price | USD/mt | MM USD/yr | % |
|---|---|---|---|---|---|
| XXXXXXXXX | XXX XXX | XXX/XXX | XXX | XXX | XX |
| XXXXXXXXX | XXX XXX | XXX/XXX | XXX | XXX | XX |
| **Gross raw materials cost** | | | **XXX** | **XXX** | **XX** |
| **Net raw materials cost** | | | **XXX** | **XXX** | **XX** |
| Net utilities cost | | | XXX | XXX | XX |
| **Operating variable costs** | | | **XXX** | **XXX** | **XX** |
| Operating fixed costs | | | XXX | XXX | XX |
| **Operating cash cost** | | | **XXX** | **XXX** | **XX** |
| Depreciation | | | XXX | XXX | XX |
| **Total operating cost** | | | **XXX** | **XXX** | **XX** |
| Corporate overhead | | | XXX | XXX | XX |
| ROCE | | | XXX | XXX | XX |
| **Product value** | | | **XXX** | | **XX** |

**Further Details**

For further clarification about the pricing assumptions used in this analysis, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

# Chapter 12

# Analysis Methodology Summary

This chapter provides a brief summary of the methodology developed by Intratec for producing its Production Cost Reports. For a more-in-depth comprehension, readers are encouraged to explore the *Intratec Commodity Production Costs – General Methodology Guide*, which can be accessed at:

► https://intrat.ec/m?f=/icc-methodology

The Intratec Commodity Production Costs report is a critical tool for evaluating industrial processes from a techno-economic perspective. Leveraging over a decade of experience in commodities markets and process economics, Intratec has developed a robust and consistent methodology to ensure reliable and comprehensive techno-economic evaluations.

A techno-economic assessment analyzes industrial processes from an economic viewpoint, considering factors such as operating costs, capital investments, and process requirements. This evaluation supports investment screening, process assessment, and the analysis of industrial ventures' economic feasibility.

The primary goal of the report is to deliver best-in-class economic evaluations, summarized as shown in Table 12.1, providing trustworthy estimates for informed decision-making. This approach offers readers clear insights into the economic viability of process technologies in dynamic markets.

To produce high-quality reports, Intratec conducts detailed research into raw materials, products, and processes, including thorough technical analyses of Inside Battery Limits (ISBL) and Outside Battery Limits (OSBL) areas. This analysis is grounded in an extensive bibliography of books, patents, and academic papers.

Table 12.1 Production Cost Datasheet Template

## Intratec Commodity Production Costs

| | | | | |
|---|---|---|---|---|
| Plant location | ________ | (e.g., USA) | **Capital investment summary** | **MM USD** |
| Period of analysis | ________ | (IC Index: ____) | Fixed capital | ________ |
| Nominal capacity (mt/yr) | ________ | | Working capital | ________ |
| Operating rate (h/yr) | ________ | (___%) | Additional capital | ________ |
| Annual production (mt/yr) | ________ | | **Total capital investment** | ________ |

| Description | Quantity per product | | Price | | USD/mt | MM USD/yr | % |
|---|---|---|---|---|---|---|---|
| Raw material 1 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| Raw material 2 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| Raw material 3 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| Raw material 4 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| **Gross raw materials cost** | | | | | _____ | _____ | ___ |
| By-product 1 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| By-product 2 | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| **By-product credits** | | | | | _____ | _____ | ___ |
| **Net raw materials cost** | | | | | _____ | _____ | ___ |
| Cooling water | _____ | m3 | _____ | USD/m3 | _____ | _____ | ___ |
| Demineralized water | _____ | m3 | _____ | USD/m3 | _____ | _____ | ___ |
| Electricity | _____ | kWh | _____ | USD/kWh | _____ | _____ | ___ |
| Steam (HP) | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| **Utilities consumption** | | | | | _____ | _____ | ___ |
| Fuel credit | _____ | MMBtu | _____ | USD/MMBtu | _____ | _____ | ___ |
| Steam (LP) | _____ | mt | _____ | USD/mt | _____ | _____ | ___ |
| **Utilities generation** | | | | | _____ | _____ | ___ |
| **Net utilities cost** | | | | | _____ | _____ | ___ |
| **Operating variable costs** | | | | | _____ | _____ | ___ |
| Operating fixed costs | | | | | _____ | _____ | ___ |
| **Operating cash cost** | | | | | _____ | _____ | ___ |
| Depreciation | | | | | _____ | _____ | ___ |
| **Total operating cost** | | | | | _____ | _____ | ___ |
| Corporate overhead | | | | | _____ | _____ | ___ |
| ROCE | | | | | _____ | _____ | ___ |
| **Product value** | | | | | _____ | | ___ |

Using this technical foundation, key process indicators, site configurations, and labor requirements are defined. These inputs are then applied to calculate capital investment and operating costs. Capital investment is categorized into fixed, working, and additional capital, while operating costs are divided into variable costs, fixed costs, and depreciation.

Accuracy is paramount, and Intratec continuously gathers comprehensive data on commodity prices, utilities, and labor costs for the specific country and period of the study. This data is sourced from both public and private entities, including national statistics bureaus, government agencies, international organizations, market exchanges, and producers.

For simplicity, all cost estimates are consolidated into a single item: the “Product Value.” This value combines operating costs (variable, fixed, and depreciation), corporate overhead, and a return on capital employed (ROCE), which reflects the capital investment.

All Intratec reports that approach industrial processes have a common structure, i.e., indexes, tables, and charts share similar standards. This ensures that Intratec’s readers know upfront what they will get and, more than that, will be able to compare technologies addressed in different reports.

Our methodology is continuously tested and validated by manufacturers, R&D centers, EPC companies, financial institutions, and government agencies that rely on our reports. Figure 12.1 illustrates the methodology used in this report.

Complementary Documents

In addition to the full analysis methodology (https://intrat.ec/m?f=/icc-methodology), Intratec provides two other documents with complementary information to this report: “Glossary & Abbreviations” and “Unit Conversion.”

The “Glossary & Abbreviations” document contains definitions of important commodity market terms found in this report and our other products. Access it at: https://intrat.ec/glossary.

The “Unit Conversion” table presents unit conversion factors for several length, mass, energy units, and more. Access it at: https://intrat.ec/unit-conversion.

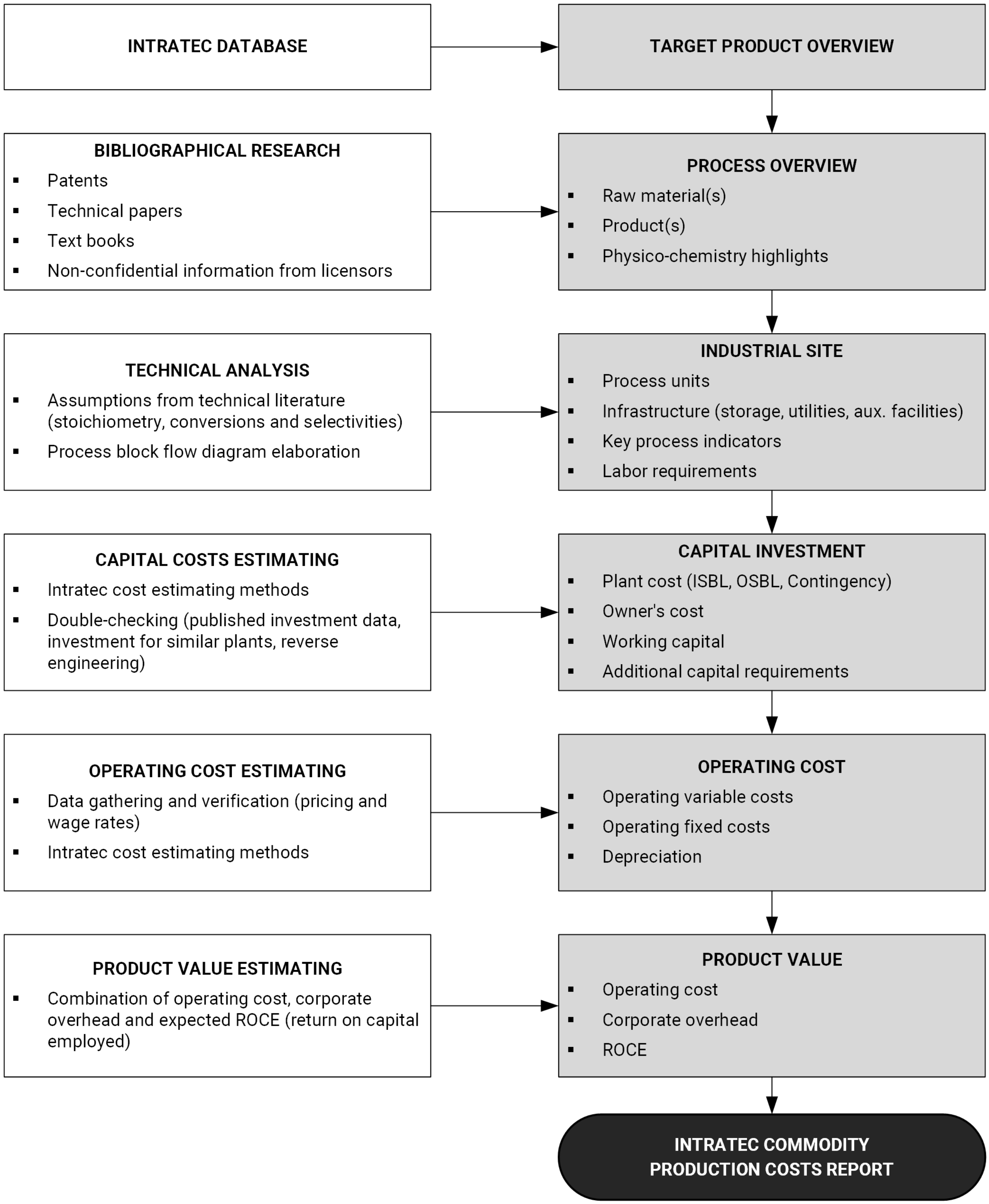


Figure 12.1 Intratec Commodity Production Costs Reports Development Methodology

# Chapter 13

# References

## Methodology References

Intratec has built its knowledge based on the most relevant text books, encyclopedias, and technical papers related to the economic evaluation of industrial processes. Such expertise has established a large foundation that enriches all Intratec reports, in a way that the reader can expect the most trustworthy information.

The methodology references reflect this foundation of bibliographical data, used in the development of all Intratec Commodity Production Costs reports, particularly in the elaboration of the methodology employed, detailed in Chapter 12.

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## Analysis References

The analysis references present the foundation of this Polycarbonate production cost report, providing information required to fully understand the industrial process addressed and to formulate the assumptions considered. These references, presented below, may encompass patents, encyclopedias, textbooks, academic or professional researches, technical papers and any other non-confidential information publicly available, duly reviewed by Intratec's team.

[A1] XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

[A2] XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

[A3] XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

[A4] XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

[A5] XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

# Appendix A

# Utilities Consumption Details

This appendix details the key utilities consumption indicators of the technology examined in the report. In other words, these indicators reflect the net utilities consumption rates per metric ton of Polycarbonate produced presented in Table A.1.

Table A.1 Net Utility Consumption Rates (per metric ton of Polycarbonate)

| Utility | Consumption per metric ton |
|---|---|
| XXXXXXXXX | XXX XXX |
| XXXXXXXXX | XXX XXX |
| XXXXXXXXX | XXX XXX |
| XXXXXXXXX | XXX XXX |

It should be noted that estimation of utility requirements in the conceptual design phase is usually fairly accurate, but tends to be somewhat low compared to real operations. Losses from vessel vents, unscheduled equipment, inerting systems, physical property inaccuracies, startup, shutdown and other process operations not typically addressed in this phase may increase utilities consumption.

# Appendix B

# Material & Utilities Pricing Data - United States

This appendix presents details of the pricing data used in the economic analysis within this report.

## Analysis Pricing Basis

The economic analysis presented is based on the prices seen in Table B.1.

Table B.1 Materials & Utilities Prices (United States, XXXX)

| Description | Price | Unit | Remark |
|---|---|---|---|
| Raw materials | | | |
| XXX | XXX | USD/XXX | XXX |
| XXX | XXX | USD/XXX | XXX |
| Utilities | | | |
| XXX | XXX | USD/XXX | XXX |
| XXX | XXX | USD/XXX | XXX |
| XXX | XXX | USD/XXX | XXX |
| XXX | XXX | USD/XXX | XXX |

## Historical Prices

The evolution of material costs over the past three years is depicted in the following pages.

# Appendix C

# Capital Costs Details - United States

This appendix details Polycarbonate plant cost, working capital, and additional capital, discussed in "*Chapter 8. Capital Costs Summary*."

## Fixed Capital Cost Details

Fixed capital constitutes the fraction of the capital investment which is depreciable. It includes the Polycarbonate plant cost and owner's cost.

### Plant Cost

The Polycarbonate plant cost, i.e., the cost related to the construction of the industrial site itself, is broken down into the components presented in Table C.1.

Table C.1 Plant Cost Estimate Accuracy Range (USD Million)

| Component | Estimate | Lower Limit | Upper Limit | % |
|---|---|---|---|---|
| Inside battery limits (ISBL) | XXX | XXX | XXX | XX |
| Process contingency (XX% of ISBL) | XXX | XXX | XXX | XX |
| Outside battery limits (OSBL) | XXX | XXX | XXX | XX |
| **Total process capital (TPC)** | **XXX** | **XXX** | **XXX** | **XX** |
| Project contingency (XX% of TPC) | XXX | XXX | XXX | XX |
| **Plant cost** | **XXX** | **XXX** | **XXX** | **XX** |

The lower and upper limits for the Polycarbonate plant cost figures, according to the accuracy range expected from conceptual evaluations presented in this report, are also presented in Table C.1. The presented range is associated with a confidence level of 90%.

Figure C.1 summarizes all items that make up the plant cost.

Figure C.1 Plant Cost Summary

**Further Details**

For more information about the breakdowns for the Polycarbonate plant capital cost, the reader is referred to "*Appendix F. Plant Cost Breakdowns.*"

## Owner's Cost

The owner's cost encompasses the expenses required to make the plant operational. Its components are presented in Table C.2.

Table C.2 Owner's Cost Details

| Component | Assumption | MM USD | % |
|---|---|---|---|
| Prepaid royalties | XX% of plant cost | XXX | XX |
| Miscellaneous costs | XX% of plant cost | XXX | XX |
| Owner's cost | | XXX | XX |

## Fixed Capital Summary

Table C.3 summarizes the fixed capital components that result in total fixed capital.

Table C.3 Fixed Capital

| Component | MM USD | % |
|---|---|---|
| Plant cost | XXX | XX |
| Owner's cost | XXX | XX |
| Total fixed capital | XXX | XX |

**Further Details**

For more information about each cost presented in this appendix, the reader is referred to https://intrat.ec/m?f=/icc-methodology

# Working Capital Details

Working capital, i.e., the funds for getting the plant into operation and meeting subsequent obligations, is broken down in Table C.4.

Table C.4 Working Capital Details

| Component | Assumption | MM USD | % |
|---|---|---|---|
| Accounts receivable | XX day(s) of total operating cost + corporate | XXX | |
| Accounts payable | XX day(s) of operating cash cost + corporate | XXX | |
| Net accounts receivable | | XXX | XX |
| Raw materials inventory | XX day(s) of raw materials costs | XXX | XX |
| In-process inventory | XX day(s) of operating cash cost + corporate | XXX | XX |
| Products inventory | XX day(s) of total operating cost + corporate | XXX | XX |
| Supplies and stores | XX% of annual operating labor & maintenance costs | XXX | XX |
| Cash on hand | XX day(s) of operating cash cost + corporate | XXX | XX |
| Total working capital | | XXX | XX |

## Additional Capital Requirements Details

Additional capital requirements are one-time expenses related to bringing a process on stream during plant start-up. Table C.5 presents the breakdown of this cost with all its components.

Table C.5 Additional Capital Requirements Details

| Component | Assumption | MM USD | % |
|---|---|---|---|
| Operator training | XX day(s) of operating + supervision labor costs | XXX | XX |
| Commercialization costs | XX% of annual operating cash cost + corporate | XXX | XX |
| Start-up inefficiencies | XX% of annual operating cash cost + corporate | XXX | XX |
| Unschd. plant modifications | XX% of plant cost | XXX | XX |
| Start-up costs | | XXX | XX |
| Land & site development | XX% of plant cost | XXX | XX |
| Total additional capital | | XXX | XX |

# Appendix D

# Operating Costs Details - United States

This appendix details utilities cost, operating fixed cost and depreciation, discussed in "*Chapter 9. Operating Costs*."

## Utilities Cost Details

Utilities cost component encompasses costs related to a plant's consumption of steam, electricity, fuel, and refrigeration. Table D.1 summarizes net utility costs for this cost analysis.

Table D.1 Net Utilities Details

| Utility | Consumption | Price | USD/mt | MM USD/yr | % |
|---|---|---|---|---|---|
| XXXXXXXXX | XXX XXX | XXX USD/XXX | XXX | XXX | XX |
| XXXXXXXXX | XXX XXX | XXX USD/XXX | XXX | XXX | XX |
| XXXXXXXXX | XXX XXX | XXX USD/XXX | XXX | XXX | XX |
| XXXXXXXXX | XXX XXX | XXX USD/XXX | XXX | XXX | XX |
| Net utility cost | | | XXX | XXX | XX |

**Further Details**

For more information about how the utilities cost components were estimated, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

Figure D.1 illustrates the utilities with greatest impact on the total utility consumption.

Figure D.1 Cost Distribution of Utility Consumption

## Operating Fixed Costs Details

Operating costs directly tied to the plant capacity, but which do not change with the operating level. Table D.2 presents the breakdown of operating fixed cost.

Table D.2 Operating Fixed Costs Details

| Component | Assumption | USD/mt | MM USD/yr | % |
|---|---|---|---|---|
| Operating labor | XX operator(s); XXX USD/oper./h | XXX | XXX | XX |
| Supervision labor | XX supervisor(s); XXX USD/oper./h | XXX | XXX | XX |
| Payroll charges | related to operating and supervision labor | XXX | XXX | XX |
| Maintenance labor | XX% of plant cost per year | XXX | XXX | XX |
| Maintenance materials | XX% of plant cost per year | XXX | XXX | XX |
| Operating supplies | XX% of maintenance costs | XXX | XXX | XX |
| Laboratory expenses | XX% of operating labor costs | XXX | XXX | XX |
| Plant overhead | XX% of operating labor and maintenance | XXX | XXX | XX |
| Property taxes & insurance | XX% of fixed capital per year | XXX | XXX | XX |
| Operating fixed costs | | XXX | XXX | XX |

## Depreciation

In this study, the depreciation unit cost corresponds to XXX USD/mt of Polycarbonate produced. This calculation was based on the straight-line method and a project economic life of 10 years for both the core production unit (ISBL assets) and owner's assets, and 20 years for the site infrastructure (OSBL assets).

**Further Details**

For more information about how operating fixed costs components and depreciation were estimated, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

# Appendix E

# Product Value Details - United States

This appendix details corporate overhead costs and the return on capital employed, both of which make up the product value, presented in "*Chapter 10. Product Value Analysis*."

## Corporate Overhead Costs Details

Corporate overhead is associated with costs incurred by a company's head office. Table E.1 presents a breakdown of corporate overhead costs.

Table E.1 Corporate Overhead Costs Details

| Component | Assumption | USD/mt | MM USD/yr | % |
| --- | --- | --- | --- | --- |
| Administration costs | XX% of operating labor and maintenance | XXX | XXX | XX |
| Information & technology | XX% of fixed capital | XXX | XXX | XX |
| Marketing & advertising | XX% of operating cash cost at full capacity | XXX | XXX | XX |
| Research & development | XX% of operating cash cost at full capacity | XXX | XXX | XX |
| Corporate overhead | | XXX | XXX | XX |

## Return on Capital Employed (ROCE)

ROCE assumptions can vary according to the industry sector and technology readiness. For this specific process a ROCE percentage of XX% was assumed. This results in an increment of XXX USD/metric ton in the product value.

Further Details

For more information about ROCE calculation, the reader is referred to https://intrat.ec/m?f=/icc-methodology

# Appendix F
# Plant Cost Breakdowns

This appendix describes details of the plant cost which comprises the costs, directly or indirectly, associated with the construction of the plant itself. Therefore, different breakdowns are presented for a better understanding of the total cost associated with the construction of the plant under analysis, as follows:

* ISBL cost by functional unit. This section provides the contribution of each functional unit portrayed in the process block flow diagram in the cost of the inside battery limits (ISBL).
* OSBL cost by piece of equipment. This section provides a distribution of the investment required for the construction of the areas that comprise the site surrounding infrastructure, as well as it details the share of the costs of each component included in these areas.
* Plant cost breakdown per discipline. In this breakdown, the plant construction costs are rearranged into an alternative perspective: direct process costs, indirect process costs and project contingency.

## ISBL Construction Cost Breakdown

In accordance with all the assumptions presented in this report, a cost estimate was developed for each functional unit inside battery limits (ISBL). Table F.1 shows the share of each functional unit.

Table F.1 Process Unit (ISBL) Construction Cost by Functional Unit

| Description | % |
|---|---|
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| Process Unit (ISBL) Construction Cost | |

Figure F.1 presents an illustration of the construction cost breakdown.

Figure F.1 Process Unit (ISBL) Construction Cost by Functional Unit

## OSBL Construction Cost Breakdown

This analysis provides a more detailed explanation of the fixed capital associated with the process described in the report.  More specifically, it is focused on the investment required for the construction of the site surrounding infrastructure, also referred to as Outside Battery Limits (OSBL), comprising support buildings, auxiliary units used for providing and distributing utilities and storage facilities.  In accordance with the configuration previously presented, a cost estimate was developed for each facility outside battery limits.

Figure F.2 presents OSBL investment broken down into each area.  The investment estimated for each area will be further detailed in the next topics.

Figure F.2   Site Infrastructure (OSBL) Construction Cost by Area

## Construction Cost: Area 90 - Storage Installations

This section details the cost estimate associated with Area 90 - Storage Installations. The components included in the estimate are detailed in the table below.

Table F.2 Area 90 - Storage Installations: Scope Description

| Component | Description |
|---|---|
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |

The following chart illustrates how each component impacts the construction cost estimate for this area.

Figure F.3 Storage Installations Construction Cost per Piece of Equipment

The cost of each component was based on the following assumptions:

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

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XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

## Construction Cost: Area 91 - Utilities Facilities

This section details the cost estimate associated with Area 91 - Utilities Facilities. The components included in the estimate are detailed in the table below.

Table F.3 Area 91 - Utilities Facilities: Scope Description

| Component | Description |
|---|---|
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |

The following chart illustrates how each component impacts the construction cost estimate for this area.

Figure F.4 Utilities Facilities Construction Cost per Piece of Equipment

The percentage associated with the remaining facilities is divided as follows:

* XXXXXXXXX - XX %
* XXXXXXXXX - XX %

The cost of each component was based on the following assumptions:

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

## Construction Cost: Area 92 - Support & Auxiliary Buildings

This section details the cost estimate associated with Area 92 - Support & Auxiliary Buildings. The components included in the estimate are detailed in the table below.

Table F.4 Area 92 - Support & Auxiliary Buildings: Scope Description

| Component | Description |
|---|---|
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |
| XXXXXXXXX | XXXXXXXXX |

The following chart illustrates how each component impacts the construction cost estimate for this area.

Figure F.5 Support & Auxiliary Buildings Construction Cost per Piece of Equipment

The percentage associated with the remaining facilities is divided as follows:

* XXXXXXXXX - XX%
* XXXXXXXXX - XX%

The cost of each component was based on the following assumptions:

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

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XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX XXXXXXXXXX

## Site Infrastructure Cost Summary

Table F.5 Site Infrastructure (OSBL) Construction Cost by Piece of Equipment

| Component | % of Total |
|---|---|
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| Area 90 - Storage Installations | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| Area 91 - Utilities Facilities | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| XXXXXXXXX | XX |
| Area 92 - Support & Auxiliary Buildings | XX |
| Site Infrastructure (OSBL) Construction Cost | 100.0 |

# Plant Cost Breakdown per Discipline

## Introduction

The primary objective of this analysis is to provide an alternative perspective on the plant capital cost. This analysis presents the plant capital cost divided in three categories: (1) direct costs (all material and labor costs associated with the process equipment); (2) indirect costs (defined by the Association for the Advancement of Cost Engineering (AACE) Standard Terminology as those “costs which do not become a final part of the installation, but which are required for the orderly completion of the installation”); and (3) contingency.

It is important to highlight that the breakdown presented within this analysis refers exclusively to the Plant Cost figure included in the report.

The composition of direct field costs and indirect costs are further detailed in the next topics. Other fixed capital components, such as Owner's Cost, are not included in this breakdown.

The following chart presents the plant cost divided in each category described above.

Figure F.6 Plant Construction Cost Summary

## Direct Costs Breakdown

Fundamentally, the direct process costs are the total installed equipment cost (from purchase to installation, including the required installation bulks). They include the following disciplines: bare equipment, equipment setting, piping, civil, steel, instrumentation & control, electrical, insulation, and painting.

Accordingly, the chart below presents the direct costs broken down by aforementioned discipline.

Figure F.7 Direct Construction Costs by Discipline

## Indirect Costs Breakdown

The indirect costs account for field indirects, engineering costs, overhead, and contract fees.

Accordingly, the chart below presents the indirect costs broken down by aforementioned items.

Figure F.8 Indirect Costs Summary

## Plant Cost Breakdown Summary

The next table presents the detailed plant cost breakdown, based on the direct and indirect costs approach. Two alternative views are presented in the table:

(1) % of BEQ. Each component is presented as a percentage of the bare equipment (BEQ) cost;
(2) % of Total. Each component is presented as a percentage of total plant cost.

Table F.6 Plant Construction Cost by Discipline

| Component | % of BEQ | % of Total |
|---|---|---|
| Bare equipment (BEQ) | XX | XX |
| Equipment setting | XX | XX |
| Piping | XX | XX |
| Civil | XX | XX |
| Steel | XX | XX |
| Instrumentation & control | XX | XX |
| Electrical | XX | XX |
| Insulation | XX | XX |
| Painting | XX | XX |
| **Direct costs** | **XX** | **XX** |
| Engineering & procurement | XX | XX |
| Construction material & indirects | XX | XX |
| General & administrative overheads | XX | XX |
| Contract fee | XX | XX |
| **Indirect costs** | **XX** | **XX** |
| **Total Process Capital (TPC)** | **XX** | **XX** |
| Project Contingency (of TPC) | XX | XX |
| **Total Plant Cost** | **XX** | **XX** |

The absolute cost of the plant is presented in the table *"Plant Cost Summary"* in *"Chapter 8. Capital Costs Summary."* It is worth noting that the process contingency presented in the aforementioned table is included within each component listed in the table above.

**Further Details**

For further information about the components included in the plant cost breakdown, the reader is referred to https://intrat.ec/m?f=/icc-methodology.

# Appendix G
# Plant Capacity Assessment - United States

This assessment presents the impact of a plant capacity change on the economic analysis presented in this report. Additional capacity scenarios were analyzed using the same methodology and compared to the base case presented in the report.

The assessment is divided into two parts: (1) a capital investment comparison, examining fixed investment, working capital and additional capital requirements; and (2) an operating costs & product value comparison.

## Capital Cost for Different Capacities

The economic analysis presented was reproduced for a range of plant capacities in order to estimate a curve that illustrates how capital investment varies with nominal plant output. This curve is presented in Figure G.1.

The minimum, mid-range and maximum capacities from Figure G.1 are compared in detail in Table G.1, which presents detailed capital cost figures to better portray how economy of scale impacts the process under analysis.

Table G.1 Capital Investment Analysis for Different Capacities (USD Million)

| | Smaller Plant | Base | Larger Plant |
|---|---|---|---|
| Capacity (mt/yr) | XXX | XXX XXX | XXX |
| | | | |
| Inside battery limits (ISBL) | XXX | XXX | XXX |
| Process contingency (XX% of ISBL) | XXX | XXX | XXX |
| Outside battery limits (OSBL) | XXX | XXX | XXX |
| **Total process capital (TPC)** | **XXX** | **XXX** | **XXX** |
| Project contingency (XX% of TPC) | XXX | XXX | XXX |
| **Plant cost** | **XXX** | **XXX** | **XXX** |
| Owner's cost | XXX | XXX | XXX |
| **Fixed capital** | **XXX** | **XXX** | **XXX** |
| Working capital | XXX | XXX | XXX |
| Additional capital | XXX | XXX | XXX |
| **Total capital investment** | **XXX** | **XXX** | **XXX** |

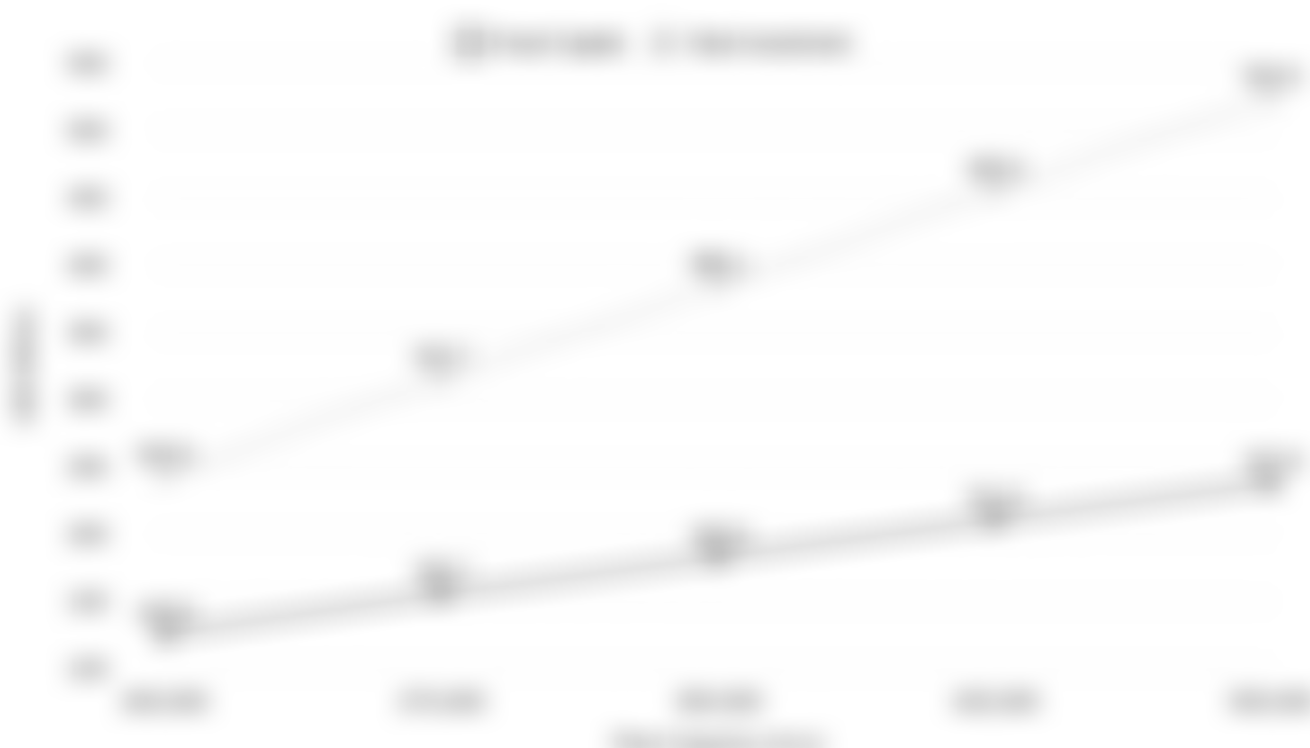

Figure G.1 Capital Investment Versus Plant Capacity

## Operating Cost for Different Capacities

The operating costs and the product value were also estimated for a range of plant capacities, resulting in Figure G.2.

A datasheet summarizing the process economics is reproduced in Table G.2, and it includes two additional scenarios evaluated in this assessment.

Figure G.2 Operating Cost Versus Plant Capacity

Table G.2 Operating Cost & Product Value Analysis for Different Capacities (USD/mt)

| | Smaller Plant | Base | Larger Plant |
|---|---|---|---|
| **Capacity (mt/yr)** | XXX | XXX XXX | XXX |
| Operating rate (h/yr) | XXX | XXX | XXX |
| Annual production (mt/yr) | XXX | XXX | XXX |
| | | | |
| Operating costs | | | |
| XXXXXXXXX | XXX | XXX | XXX |
| XXXXXXXXX | XXX | XXX | XXX |
| **Gross raw materials cost** | **XXX** | **XXX** | **XXX** |
| **Net raw materials cost** | **XXX** | **XXX** | **XXX** |
| Net utilities cost | XXX | XXX | XXX |
| **Operating variable costs** | **XXX** | **XXX** | **XXX** |
| Operating fixed costs | XXX | XXX | XXX |
| **Operating cash cost** | **XXX** | **XXX** | **XXX** |
| Depreciation | XXX | XXX | XXX |
| **Total operating cost** | **XXX** | **XXX** | **XXX** |
| Corporate overhead | XXX | XXX | XXX |
| ROCE | XXX | XXX | XXX |
| **Product value** | **XXX** | **XXX** | **XXX** |

# Appendix H

# Project Implementation & Construction Schedule

This appendix aims to present a preliminary project implementation schedule, encompassing the period from the decision to invest to the start of commercial production.

This is divided into five major steps:

(1) Basic engineering;

(2) Detailed engineering;

(3) Procurement;

(4) Construction; and

(5) Start-up.

The duration of each project phase is detailed in Table H.1.

Table H.1 Project Phases Schedule

| | Phase Start | Duration |
|---|---|---|
| | Months after project started | Months |
| Basic engineering | XX | XX |
| Detailed engineering | XX | XX |
| Procurement | XX | XX |
| Construction | XX | XX |
| Commissioning & start-up | XX | XX |

Since the project phases overlap, the total project duration is not equal to the sum of each phase duration. The Engineering, Procurement & Construction (EPC) period - from the basic engineering start until the end of construction - is about **XX months**. The total project duration, also including commissioning and start-up, is approximately **XX months**.

Figure H.1 illustrates the project implementation and construction schedule and clarifies the overlaps among the distinct project phases.

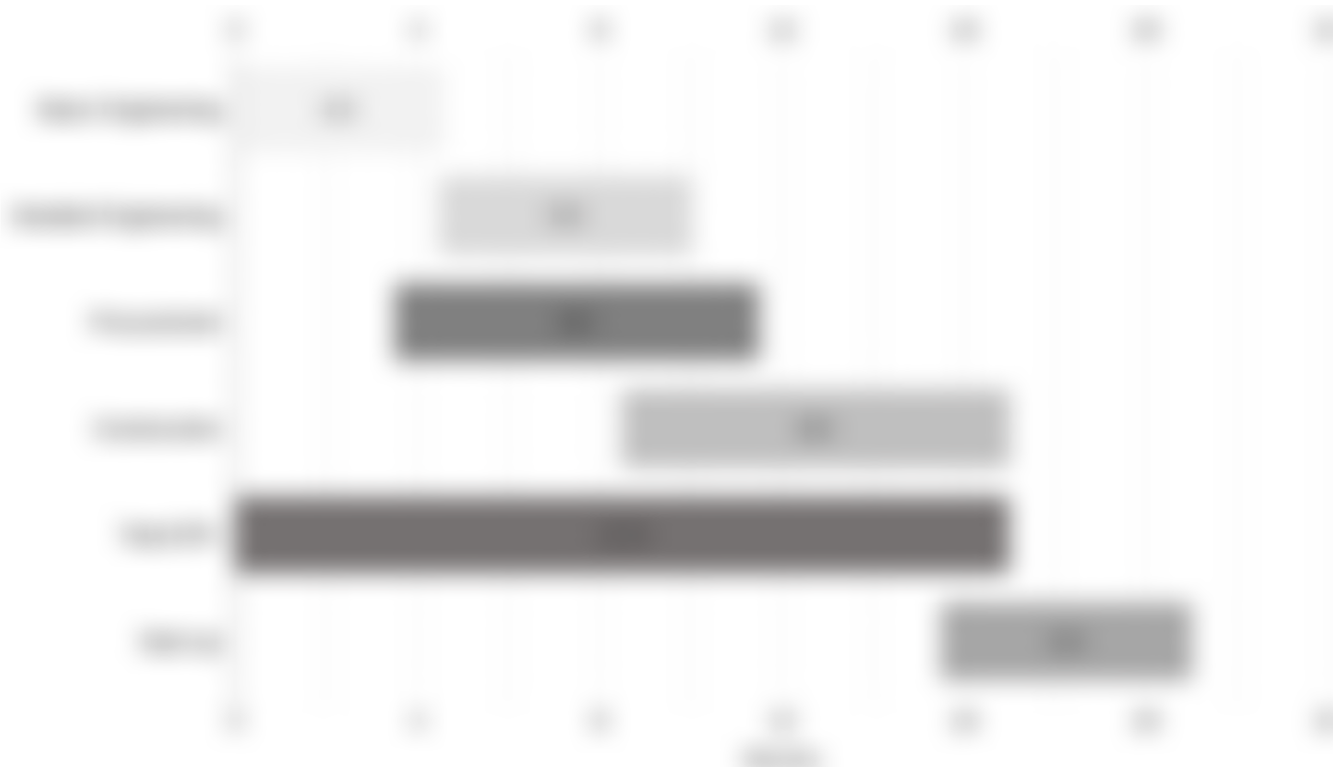

Figure H.1 Implementation & Construction Schedule

# Appendix I

# Process Flow Diagrams & Equipment List

This chapter comprises a schematic representation of relevant operations of the process examined in this report. It indicates process operations, main process streams, main pieces of equipment and utilities consumed.

For better comprehension, the main conventions for equipment tags and symbols for lines used in the process flow diagram are listed in Figure I.1 and Figure I.2.

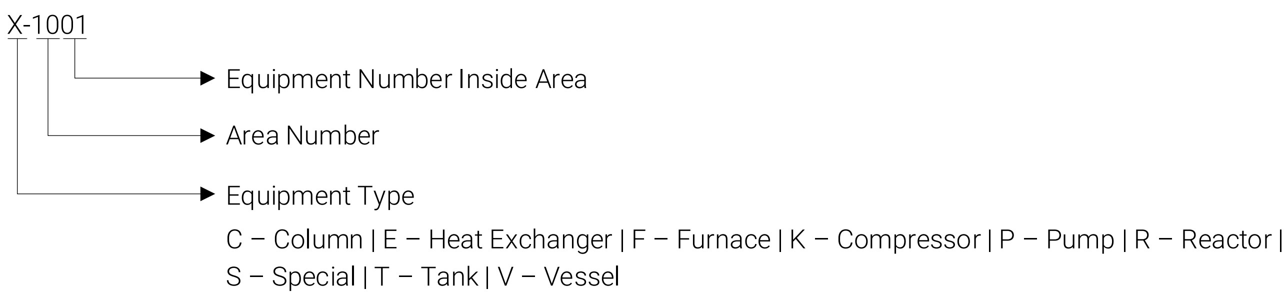


Figure I.1 **Convention for Process Equipment Tags**

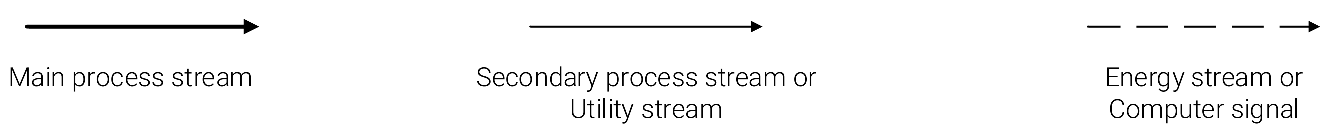


Figure I.2 **Symbols for Lines**

Table I.1 and Table I.2 present the different codes used along with their definitions.

Table I.1 Diagram Legend - Utilities

| Code | Definition |
|---|---|
| BFW | Boiler feed water |
| CW | Cooling water |
| DW | Demineralized water |
| FU | Fuel |
| HTF | Heat transfer fluid |
| N2 | Nitrogen |
| O2 | Oxygen |
| PC | Process condensate |
| PW | Process water |
| RF | Refrigerant |
| RW | Refrigerated water |
| ST | Steam |

Table I.2 Diagram Legend - Equipment Type

| Code | Definition |
|---|---|
| C | Column |
| E | Heat exchanger |
| F | Furnace |
| K | Compressor |
| P | Pump |
| R | Reactor |
| S | Special |
| T | Tank |
| V | Vessel |

Furthermore, most of the symbol standards adopted in the development of the diagram are presented in the next figures.

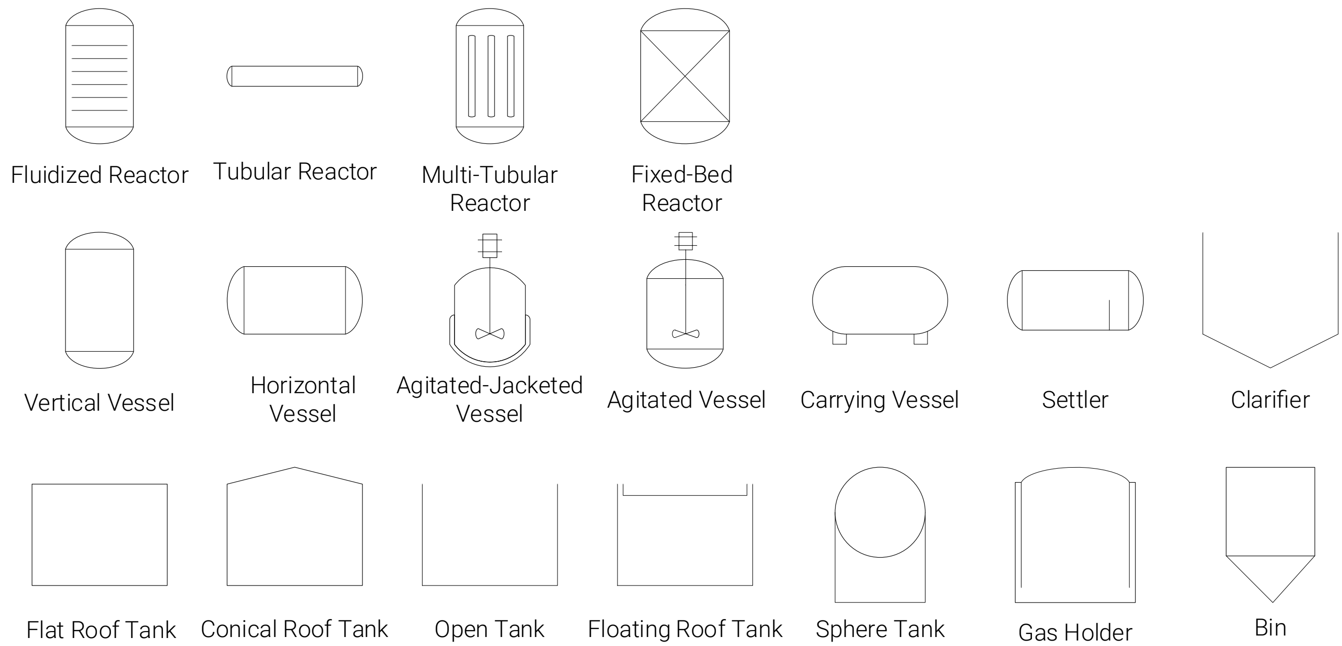


Figure I.3 Equipment Symbols - Reactors & Vessels

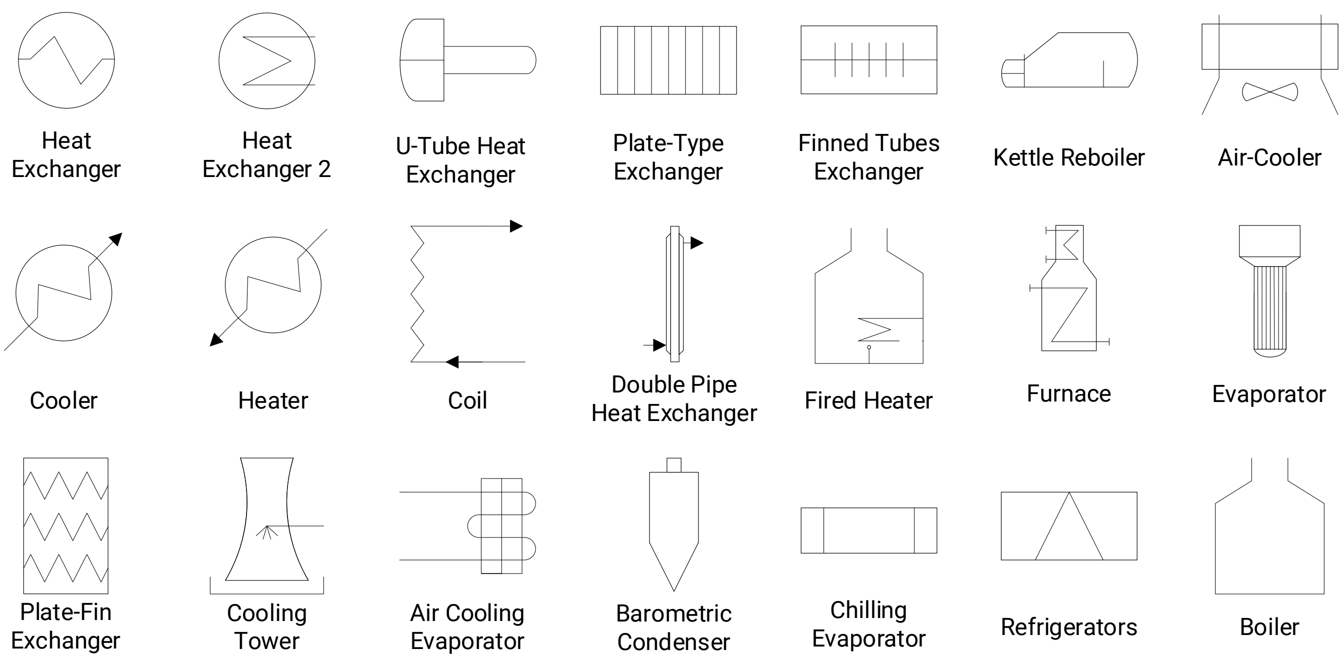


Figure I.4 Equipment Symbols - Heat Exchangers

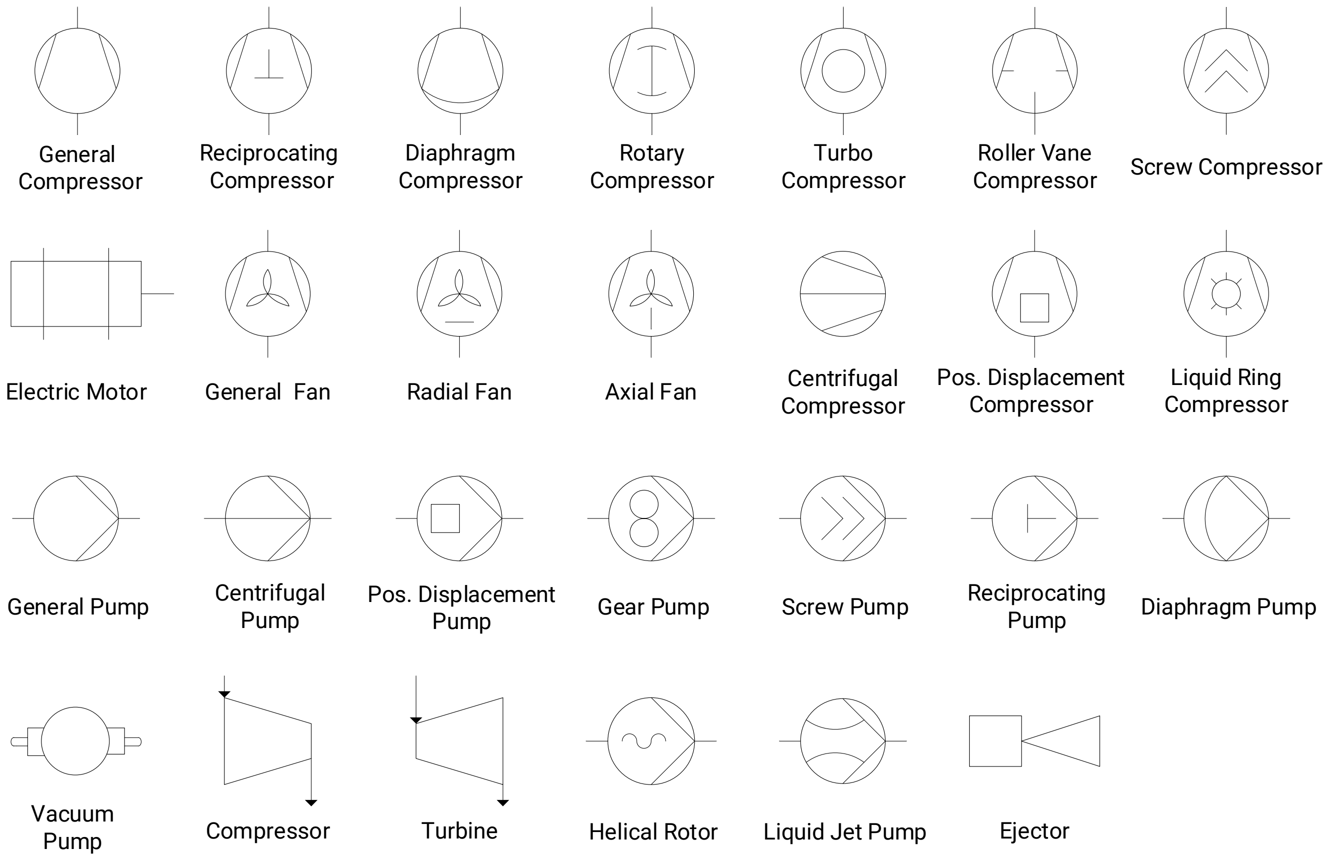


Figure I.5 Equipment Symbols - Compressors & Pumps

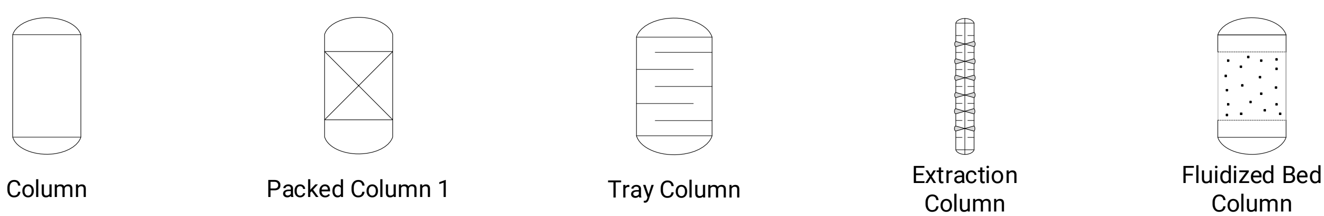


Figure I.6 Equipment Symbols - Columns

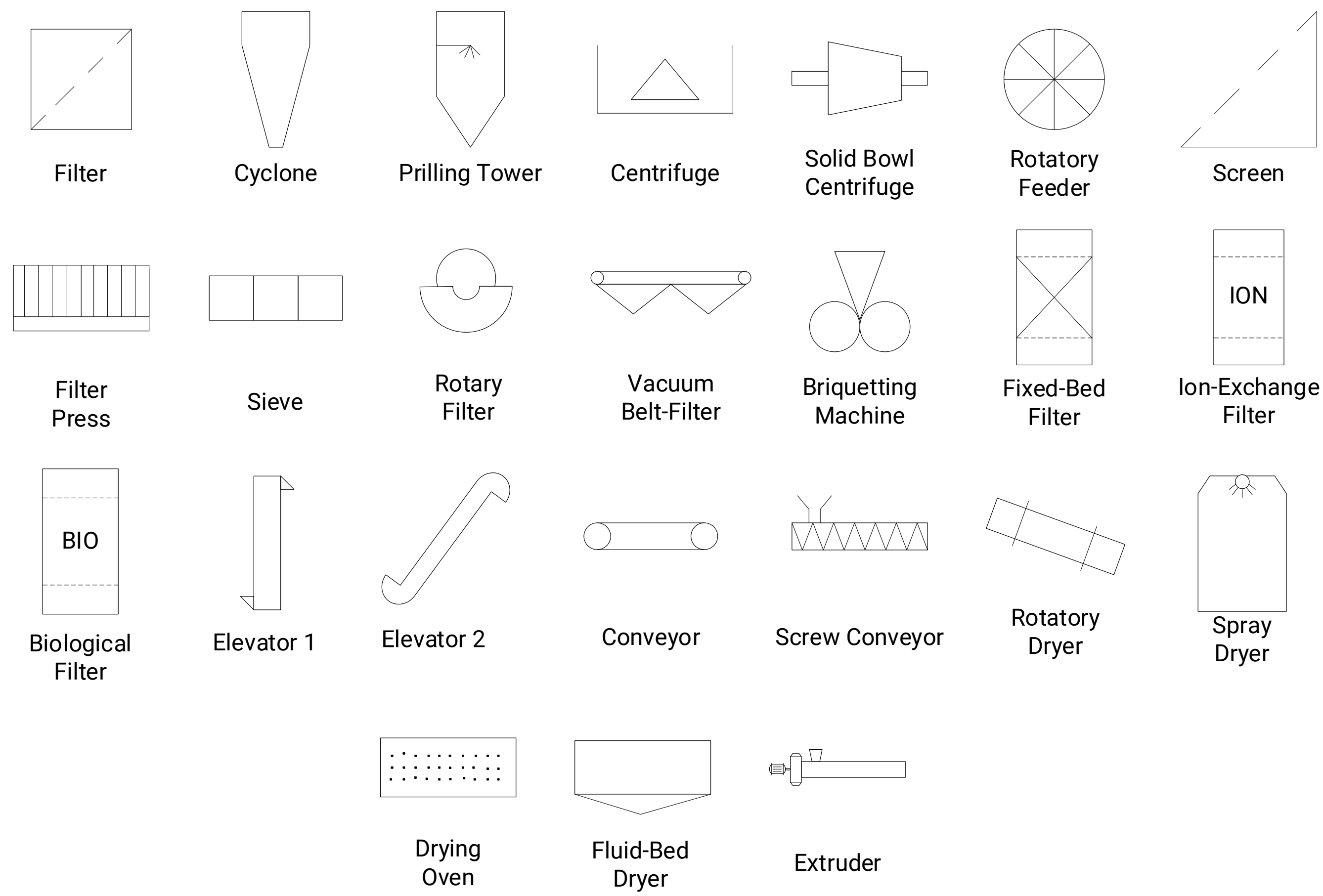


Figure I.7 Equipment Symbols - Solids Processing

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# Appendix J

# About Intratec

## Our Business

In operation since 2002, Intratec is a B2B leading provider of commodity strategic data and analyses. Our mission is to provide companies with reliable information about the commodities, empowering our customers to make accurate, high value-added decisions.

Our AI-driven reports and analyses present independent, trustworthy data so that our customers can focus on what they do best. Our website is an e-commerce resource where customers easily learn about Intratec offerings and promptly order what they need. Our products focus on key information surrounding commodities such as prices, trends and forecasts, as well as cost structures of production processes. Our expertise spans the following commodity sectors: Oil & Energy, Fertilizers & Gases, Olefins & Derivatives, Aromatics & Derivatives, Alcohols & Organic Acids, Inorganic Chemicals, Polymers, Food & Nutrition, Metals & Mining, Pharmaceuticals and Water & Utilities.

With well-designed offerings, we serve a diverse group of customers, from Fortune 500 companies and local manufacturers to biotech startups and consultants. Our studies and data have been used in multiple ways, such as:

* To evaluate transaction prices in international markets
* To identify monthly/yearly price trends
* To assess procurement planning performance
* To obtain estimates of capital and operating costs of industrial plants
* To learn about the economic potential of R&D breakthroughs

* To screen and assess industrial investment options

# Our Products

## Intratec Commodity Production Costs

Intratec Commodity Production Costs, like this one, are best-in-class professional reports examining production processes, with independent and up-to-date analyses of capital and operating costs. We offer reports focused on technologies for the manufacture of +250 commodities, spanning a diverse range of industries including Oil & Energy; Fertilizers & Gases; Olefins & Derivatives; Aromatics & Derivatives; Alcohols & Organic Acids; Polymers; Inorganic Chemicals; Food & Nutrition; Metals & Mining; and Pharmaceuticals.

Our reports detail technologies within a wide range of maturity, from established processes to embryonic/emerging technologies. Also, our reports examine a variety of manufacturing techniques, targeting transformation processes (e.g., nitrile gloves production), processes for fabric and fibers production (e.g., nonwoven, carbon fiber), polymerization processes (e.g., PP, PE, PVC), electrolytic processes (e.g., chlorine, caustic soda), fossil-based/petrochemical processes (e.g., propylene, ethylene), processes for the production of green chemicals from renewable sources (e.g., bioethanol, bio-based succinic acid) and others. Our Reports Library can be found at:

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Intratec Energy Price References are provided as an annual subscription where subscribers have access to trustworthy and independent pricing data of 13 key energy commodities in 33 strategic countries worldwide.

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## Intratec Industry Economics Worldwide

Intratec Industry Economics Worldwide provides reliable, independent information on the economic scenario of up to 33 countries. This product allows subscribers to perform their own worldwide economic analysis using a combination of three powerful tools: Intratec Industrial Utilities Prices & Costs, Intratec Plant Construction Cost Indexes, and Intratec Plant Location Factors.

Intratec Industry Economics Worldwide can be accessed through various delivery methods: online charts for dynamic exploration, an Excel Add-In for quick updates, and an API for seamless integration into existing workflows. Learn more about each of the tools included in this product, below:

* Intratec Industrial Utilities Prices & Costs

Intratec Industrial Utilities Prices & Costs offers trustworthy, independent references for evaluating the costs of key utility commodities across multiple strategic countries. Subscribers can access both historical data and forecasts of generation costs and contract prices, all displayed in a user-friendly tool. Additionally, data are made available through Excel Add-In for quick updates and API for seamless integration into existing workflows.

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Intratec Plant Construction Cost Indexes (IC Indexes) are multipliers designed to adjust industrial plant construction costs over time. Unlike other indexes limited to the USA, IC Indexes allow for the updating of construction costs in up to 33 countries, making them suitable for industrial processing plants across various sectors. These indexes offer a monthly series measuring changes in capital expenditure (capex) for building industrial plants, providing an efficient method to instantly adjust past construction cost data to reflect current costs.

* Intratec Plant Location Factors

Intratec Plant Location Factors (IL Factors) are multipliers designed to convert industrial plant construction costs from one country to another.  These factors allow for the estimation of capital expenditure (capex) by applying a straightforward calculation: simply multiply the known plant construction cost from a reference country by the corresponding location factor.  Suitable for industrial processing plants across various sectors, the IL Factors cover 33 key countries, providing an efficient method for adjusting plant construction costs between different geographical locations.

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# Appendix K

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COMMODITY PRODUCTION COSTS

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