5.3.4 Economics

The carbothermic reduction of quartz in the submerged arc furnace consumes large amounts of energy and material. Best industrial performances are 10 to 11 MWh per metric ton (MT) of silicon metal and 90% silicon yield. Both availability and price of electrical power and raw material such as quartz and coal are therefore extremely sensitive to the silicon metal economics. Boardwine *et al*. [22] have presented the average structure for direct cost for Western producers as follows:

Reduction materials (as coal)	20%
Quartz	9%
Electrodes	12%
Electric power	21%
Supplies and equipment	16%
Labour	17%
Transport (to customers)	5%

In spite of dramatic changes and improvement for the individual producers, particularly with the development of new electrode technologies, the above figures are probably still valid for a large group of plants.

Most of the silicon plants are 20 years or more old. New capacity has been added during the past 10 years mainly by converting ferrosilicon furnaces to silicon. High capital expenditure is a barrier to new expansion. Investment of one million US dollars per one thousand MT of silicon is proposed as an indicating information for new furnaces.

A general and detailed source of information on production of metallurgical grade silicon is found in the recent book *Production of High Silicon Alloys* by Schei *et al*. [23].

5.4 PRODUCTION OF SEMICONDUCTOR GRADE SILICON (POLYSILICON)

Impurities in the ppb(a)–ppt(a) range are required for polysilicon supplied to the semiconductor industry. The ultra-high purity is needed to ensure exacting semiconductor properties in the grown silicon crystals. This is achieved first by the preparation of a volatile silicon hydride and its purification generally using fractional distillation. This is followed by the decomposition of this hydride to hyperpure elemental silicon by reductive pyrolysis or chemical vapour deposition. The preparation of the volatile Si compound involves external reactants and its decomposition generates by-products, which need to be recycled. The various polysilicon routes therefore must control four successive steps. All have a strong impact on the overall feasibility and economics of the suitable polysilicon products:

1. preparation/synthesis of the volatile silicon hydride
2. purification