# A FEASIBLE APPROACH TO IMPLEMENT A COMMERCIAL SCALE CANDU FUEL MANUFACTURING PLANT IN EGYPT



I. EL-SHEHAWY* , M. EL-SHARAKY* , K. YASSO* , I. SELIM*,
N. GRAHAM ** AND D. NEWINGTON**

* Nuclear Power Plants Authority , Cairo ,Egypt
** Zircatec Precision Industries Inc., Port Hope ,Canada

## ABSTRACT

Many planning scenarios have been examined to assess and evaluate the economic estimates for implementing a commercial scale CANDU fuel manufacturing plant in Egypt. The cost estimates indicated strong influence of the annual capital costs on total fuel manufacturing cost; this is particularly evident in a small initial plant where the proposed design output is only sufficient to supply reload fuel for a single CANDU-6 reactor. A modular approach is investigated ,as a possible way , to reduce the capital costs for a small initial fuel plant. In this approach the plant would do fuel assembly operations only and the remainder of a plant would be constructed and equipped in the stages when high production volumes can justify the capital expenses. Such approach seems economically feasible for implementing a small scale CANDU fuel manufacturing plant in developing countries such as Egypt and further improvement could be achieved over the years of operation.

## 1 . INTRODUCTION

Nuclear Power Plants Authority , NPPA , is given the mandate to implement the Egyptian nuclear power program for electricity generation . In its role , NPPA initiated studies to assess the direction Egypt should take in developing the nuclear power program. Setting out the criteria to be self reliant for the nuclear supplies , one of the main objectives of these studies was to investigate and evaluate national industry capabilities . The findings showed that the local industries could participate in producing a considerable percentage of the different components of a nuclear power plants (1) . Referring to introducing CANDU nuclear power reactors in Egypt , the studies provided encouraging results pertaining to the potential participation of national industry in manufacturing CANDU fuel (2) . Aiming at maximizing local participation for supplying CANDU fuel components , a two stage program to develop localization capabilities was initiated jointly with Canadian and US firms .

The objectives of the first stage , i.e. Technology transfer program , were directed to develop familiarity with technical parameters of CANDU-6 fuel and to establish local capability to manufacture experimental fuel bundles . In-reactor irradiation and the results of post-irradiation examinations will show experience that has been gained .

The overall target of the second stage was devoted to provide a technical and economical feasibility study for establishing a commercial scale CANDU fuel plant in Egypt . During the course of study, all key elements of the conceptual plant are explored . Also , maximum local participation in the plant project is considered . In addition , the economic incentives for manufacturing fuel bundles locally , compared to importing them are examined . Furthermore , the influence of production capacity on economic estimates is evaluated . The purpose of this work is to outline one of findings of this study with a particular intent to discuss the effectiveness of applying staged capital approach , as a possible way , to implement a small scale commercial CANDU Fuel manufacturing plant in developing countries such as Egypt .

## 2. STUDY OBJECTIVES AND SCOPE

With a view of enhancing local participation , the on-going requirement for fuel supply for a proposed CANDU reactor units in Egypt has been considered . The efforts have been directed to carry out a study in order to investigate the technical aspects and to assess the economic basis for establishing a commercial fabrication plant for CANDU fuel . The study aimed at explore the essential key elements of the conceptual fuel plant . These include site selection , facility licensing , plant design and construction , equipment supply and installation, manufacturing qualification , staffing and plant operation . A Further objective was to identify and maximize localization in sourcing the supply of services , components , and maintenance and operations for the proposed fuel plant . Finally the main goal was to estimate fuel manufacturing costs in Egypt .

Throughout the scope of study , all sources that contribute to the cost of fuel manufacturing are examined . These include capital costs , principally for the building , equipment and foreign technical assistance during construction and commissioning periods, and operating costs which are mostly for materials, services and labor. The estimated costs of fuel manufacturing , for a range of 100 TeU up to 400 TeU per year of plant production capacities , are compared to the estimated cost of fuel that could be obtained from foreign sources .

## 3. COST ESTIMATES AND EVALUATION

### 3.1 Ground Rules

In order to assess and evaluate the estimates of local fuel manufacturing cost , the following basis are assumed :

1- The plant size shall accommodate the supply of reload fuel for four CANDU-6 size nuclear reactors ; although the initial requirement would be a fuel production capacity of one CANDU-6 reactor , i.e. the equivalent of 100 TeU per year .

2- The uranium material , as ceramic grade UO2 powder , is owned by the nuclear utility and would be supplied free-issue to the fuel plant.

3- The Zirconium materials for the fuel bundle assemblies would be obtained from foreign suppliers .

4- The plant construction and manufacturing start - up schedule is estimated to be six years after approval of the project . If an earlier start-up date is needed , this schedule could be reduced to approximately five years by a staged start - up of plant operation ; this would require early completion and operation of only the assembly process area of the plant - as shown in Figure (1).

5- The cost estimates are based on a uniform depreciation rate of capital costs over a period of fifteen years after production start-up , 10 % per year interest rate and 3 % escalation rate to estimate cost at the time of production start-up.

6- A cost of purchasing manufacturing fuel services on the open market , on the basis 1994 US dollars , is assumed by a CANDU fuel manufacturer; i.e. Zircatec Precision Industries Inc. This cost is taken as a guide for cost comparison purposes in the study and for normalization processes throughout this work.

## 3.2 Cost Analysis Structure

The total fuel manufacturing cost when the plant is in production are made up of operating costs and a cost for write-off or depreciation of the plant capital costs. These costs , on an annual basis , are related to the annual fuel production capacity to be in terms of $ / kgU produced .

The operating costs , on an annual basis , include the costs of all materials and parts that make up the fuel bundle , the cost of maintenance , the cost of plant staff and labor and any other costs associated with plant operation .

The cost write-off of the plant capital costs , also on annual basis, is made up of an amount for capital cost depreciation and an amount for interests on the capital cost remaining after depreciation balance .

## 3.3 Fuel Cost Estimates

The normalized estimated costs of manufacturing fuel during the first year of production in a **fully integrated plant** corresponding to its production capacities; i.e.100 up to 400 TeU per year ,are shown in Figure (2) . The figure indicates highest cost of fuel manufacturing in the small output plant compared to that in larger output plants. Furthermore, the figure shows the strong influence of capital costs on plant capacity and a less dependency of production capacities on operating costs. Comparing to estimated open market cost, it is evident that the fully integrated fuel plant with 300 TeU/Y initial capacity or more would be economically competitive.

An analysis for assessing the impact of accumulated interest rates that might prevail during the construction period is performed and its trend is shown in Figure (3). Due to significant reduction in the annual capital cost charges corresponding to lower interest rate than 10%, the analysis concluded that a plant of production capacity of 200 TeU/Y would be economically competitive comparing to international market cost if the interest rate could be reduced to 5% per year. However the trend shows the great sensitivity of capital costs to interest rate particularly in small initial fuel plant; i.e. 100 TeU/Y .

To reduce the effect of capital costs on the fuel manufacture cost for small initial capacity plant, the **staged start-up** option is firstly examined. It is proposed that only the assembly area of the plant would be made operational, according to the short schedule, while the constructed UO2 pellet and sheath assembly areas became operational sometime latter. Figure (4) illustrates the estimated costs for staged start-up plant versus fully integrated for small fuel plant capacity, i.e. for 100 TeU per year. The figure shows that although the capital cost charges are reduced, this effect is strongly off-set by higher operating costs. The higher annual operating costs are due to additional costs for the importing of semi-finished fuel bundle components.

## 4. MODULAR PLANT APPROACH

Estimates of the total fuel manufacturing cost indicated that the cost is high , particularly in small capacity plant . The high cost is influenced significantly by higher capital cost charges in the fully integrated plant and affected mainly by higher operating costs in the staged start-up plant. In an effort to reduce total fuel manufacturing cost in this small output plant, a **staged capital investment** is suggested. In this approach, only the fuel assembly operations are considered in the initial manufacturing stages; the pellet and sheath process areas could be planned but would be constructed and equipped in stages when higher required capacities would justify the additional investments. In this suggestion , the plant building would be a module to accommodate only the element and bundle assembly manufacturing area and the associated inspection facilities and staff offices.

The estimated costs to provide this first stage for fuel assembly operations only comparing to those for fully integrated are shown in Figure (5). The capital cost estimates indicate that the capital costs corresponding to modular approach are reduced by about 60% . Regarding the operating costs in this suggested modular approach, it appears higher than those estimated for fully integrated plant but more reduction could be achieved by increasing local supplies. In summary comparing the estimated total cost of manufacturing fuel for the modular plant with those estimated for a fully integrated and for a staged start-up option for a fuel plant with small capacity ; 100 TeU/y , indicates a 25 % reduction for the modular assembly-only plant comparing to fully integrated plant and a reduction of 30 % relative to staged start-up plant .

## 5. SUMMARY AND CONCLUSIONS

The estimated fuel manufacturing cost associated with implementing a commercial scale CANDU fuel manufacturing plant in a developing country such as Egypt indicates that the cost is very volume dependent . A full-scale fuel plant at a rate of greater than 300 TeU per year could be economically competitive with fuel purchased on the international market , such plant could be feasible to provide fuel for three or more CANDU-6 reactor units . Under a provision that the capital funds could be obtained at lower interest rate, i.e. 5% , the estimated fuel manufacturing cost would be competitive for a 200 TeU/Y capacity plant .The cost of fuel from a small plant of lower capacity , such that required to provide a reload fuel for a single CANDU-6 reactor , would be high due to unduly high capital cost charges .

In order to reduce the impact of capital costs in an initial small capacity fuel plant , a modular plant for fuel assembly only is recommended . In this modular approach , the site plan would include the proposed fuel scale fuel plant but the initial construction would include only the fuel assembly and office areas. Although the annual operating costs in this approach would be high ., due to the need to import semi-finished fuel components , the lower capital costs would off-set these to some extent . Efforts to localize operating costs through increasing local manufacture of semi-finished components and the experience gained over years of operation of the modular initial plant , would further reduce the fuel costs and improve the plant's economic competitiveness.

## 6.ACKNOWLEDGMENT

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## 7. REFERENCES

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(2) Higgy.H.R, " Program to Develop Localization Capabilities", 5th Conf. Nuclear Science & Applications, Vol.1, 302-324, Cairo, Egypt, 1992.

## CANDU FUEL

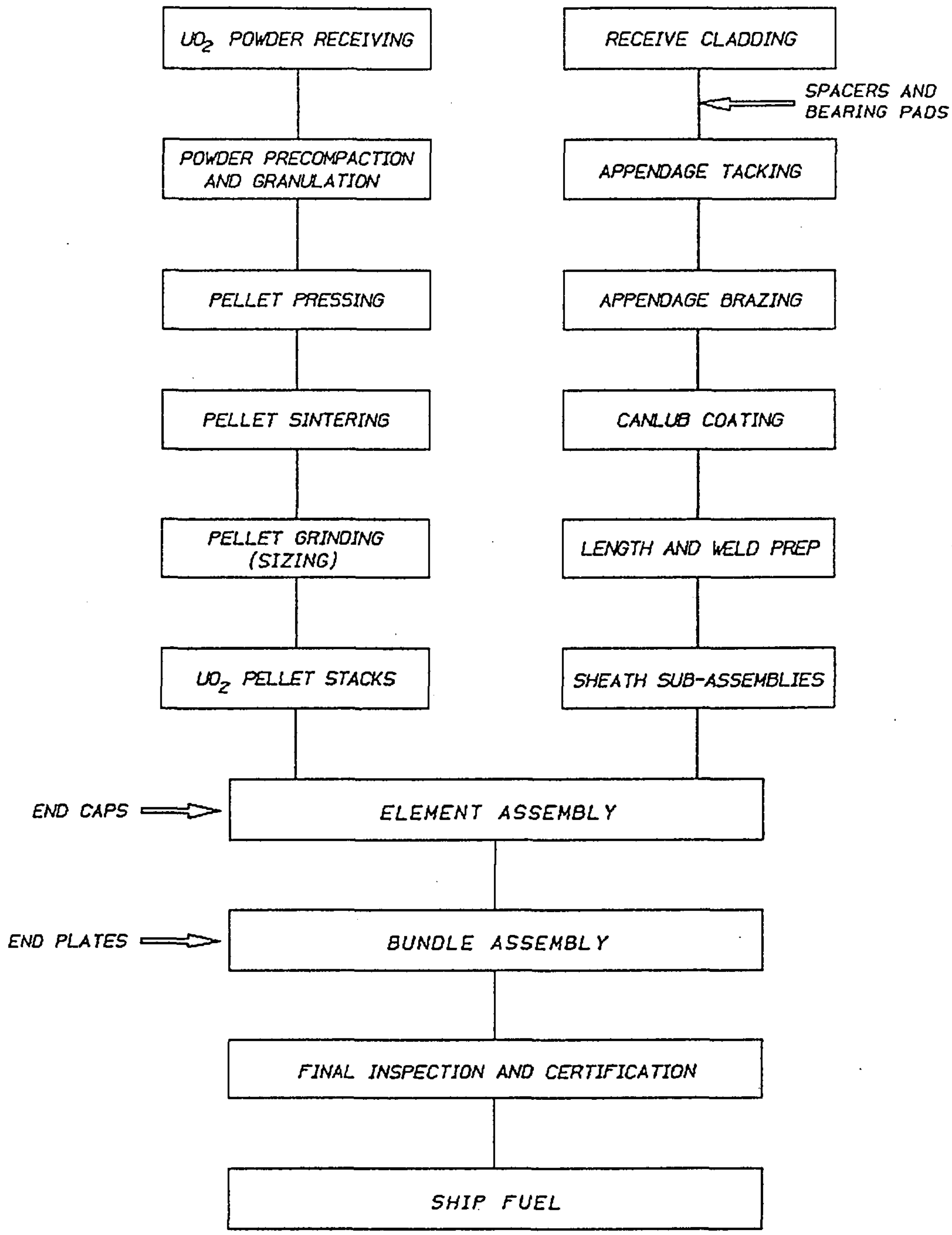


FIGURE 1
PROCESS FLOW CHART

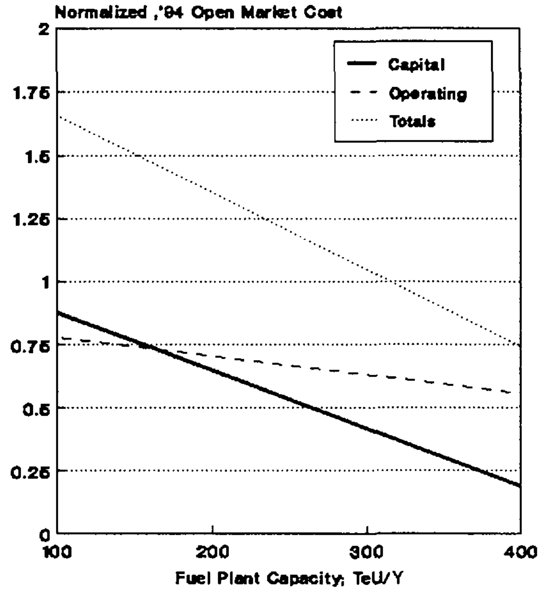


**FIGURE 2: FUEL MANUFACTURING COSTS TREND**
**FULLY INTEGRATED FUEL PLANT**
(Dep. 15 Years, 10% Interest Rate)

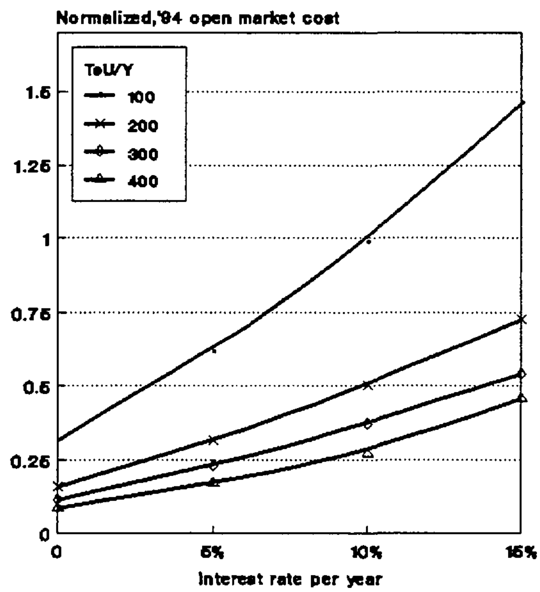


**FIGURE 3: EFFECT OF INTEREST RATES ON ANNUAL CAPITAL COST CHARGES FOR FULLY INTEGRATED FUEL PLANT**

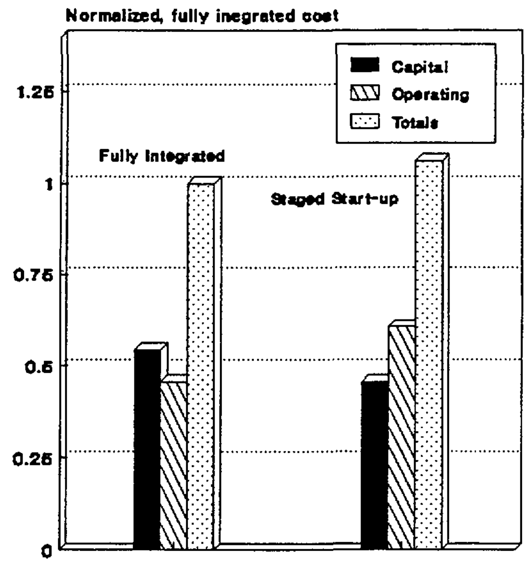


**FIGURE 4 : FUEL MANUFACTURING COSTS FOR 100 TeU/Y INITIAL PLANT CAPACITY (FULLY INTEGRATED VS STAGED START-UP)**

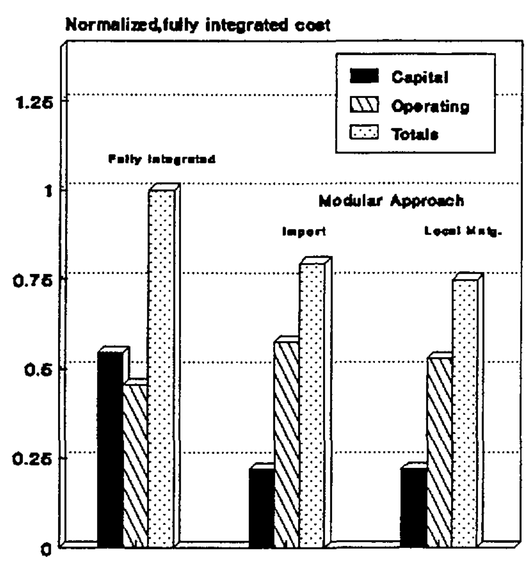


**FIGURE 5 : FUEL MANUFACTURING COSTS FOR MODULAR CAPITAL INVESTMENT VS FULLY INTEGRATED PLANT; CAPACITY OF 100 TeU/Y**

## *Session 2A: Performance Assessment*

*(Chair: D.E. Teed, GE Canada)*