THE INGA DEVELOPMENT
What in the last 40 years, what in future

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1. PREAMBLE

- Many thanks to WEC for my inclusion in the WEC Task Force for the Grand Inga development. It has been a real pleasure to work during these two months to prepare this meeting with Elias Velasco and the other Spanish and African friends, with WEC London office and with Lahmeyer.
- I am an old engineer and this involvement has rejuvenated me, has brought me back to the 1960's when I started to do in Cesi my first studies on Inga. Inga came back later on many times in my career with various feasibililty studies but also for the involvement in the construction and rehabilitation of the longest transmission line of the world: the Inga-Kolwezi 1700 km HVDC ±500 kV line that allows to have in the heart of Africa a "virtual hydro plant" of more than 1000 MW.
- I will try with my talk to summarize the **main results of the presentations** and discussions **of yesterday**, **to summarize the main studies performed and what done** up to now for Inga **and to provoke** with some comments **your interventions**. Your contributions are essential for a real pragmatic approach to make the Grand Inga happen for Africa, to become a reality and not only a good business for consultants or for intellectual, technical and philanthropic discussions.

2. MAIN INFO FROM MARCH 16 PRESENTATIONS/DISCUSSIONS

- **Energy is a prerequisite for development**; Africa has 14% of world population but it accounts for only 3% of energy consumption. South Africa, with less than 5% of African population, absorbs around 50% of all African energy consumption. If one does not consider S. Africa, the **per capita annual consumption of electricity is less than 300 kWh** compared to the 14,000 in US.
- If we do not consider North Africa countries and South Africa, the energy requirements of all the other African countries are met 85% through wood/deforestation. The **number of people in Africa with no access to electricity is exceeding 500 million and it is going to increase**.
- The **hydro-potential in Africa** of more than 230 GW **is exploited only for 7%;** Congo alone has a potential of 100 GW. In terms of hydro energy, Congo has a potential of 500 TWh, Ethiopia of 160 TWh, Cameroon 160 TWh, Angola 25 TWh.
- **Egypt** has now 21 GW of installed capacity with necessity of great expansion due to expected load growth of 7% per year. Following their involvement in the 1997 Inga study, they continue to be very interested in getting energy from Grand Inga.

- **Nigeria** power needs in 2015 are 30 GW and 3500 MW are foreseen to come from Inga.
- **South Africa** energy requirements and WESTCOR program involving 5 countries with energy from Inga 3 has been presented in details and I leave to Pat Naidoo to talk about that.
- With reference to **project economics for the specific Grand Inga project**, we have had from Lahmeyer some preliminary updating at 2007 of the 1997 envisaged cost of the “Feasibility Study: **Egypt/DRC Power System Interconnection study”.**

In synthesis:

	1ST STAGE	2ND STAGE	3RD STAGE	4TH STAGE
P IN INGA	6,000 MW	12,750 MW	19.500 MW	24,500 MW
P GUARANTEED	4,000 MW	8,000 MW	12,000 MW	16,000 MW
TOTAL BILLION $	~ 19	~ 31	~ 43	~ 55
GENERATION	40%	34%	32%	29%
TRANSMISSION	60%	66%	68%	71%

- We have got nice **info on the prerequisites to avail financing for a project like Grand Inga** and we have got details on the specific example of the Lao-Tai project involving MFA (Multinational Finance Agreements), BFA (Bilateral Financial Agreements) and Export Credits, in addition to special legislations/risks coverage agreements and governmental guarantees.
- We have got confirmation that the **HVDC technology for the Grand Inga transmission exists.** Gigantic jumps both in voltage (up to ±800 kV) and in power (up to 6000 MW and above) have been done for the converter stations and a bid for these type of stations is under emission in China. New cheap and easy to control "multi-terminals" to deliver power to crossed countries are being proposed. For OHTL's there is a well established technology and various alternatives are possible for HVDC ±800 kV solutions, depending on logistics and local conditions. Some assessment must be done for insulations in desert areas and for the application of composite insulators.
- **The environmental impacts** must be carefully considered and special attention should be paid to GHG emissions from reservoirs in tropical areas.

- Interesting info have been provided on the huge **3 Gorges China hydro project of about 23 GW** installed in one plant. The total cost is of 23 billion dollars for generation and 7 billion dollars for transmission (average distances of around 500 km). 20 years from initial feasibility study to the operation of the first unit.
- Detailed legal, financial and technical data have been provided on the binational **Brasil/Paraguay Itaipu hydro project of 14,000 MW**. The plant is providing around 95 TWh year with very high availability; its cost is 11.7 billion US$ for investment and 7.9 billion US$ for interests. The transmission (2 HVDC lines ±600 kV and 3 AC 800 kV lines of about 800 km each) belongs to a different company which has spent around 7 billion US$.
- The overall conclusion is:

  Inga is an unique place in the world for a cheap, easy and simple and very large hydro power plant with no practical impact on the environment. Inga can be a substantial contributor to the socio-ecnonomic-political development of Africa. …., but the main loads are very far from the plant.

3. MAIN HISTORY OF INGA

3.1 ***1960's-1970's*: SICAI Study**

- definition of potential power from PIOKA/INGA/MATADI up to 60,000 MW - 500 TWh/year
- development of:
  - INGA 1 - INGA 2 (350 MW + 1425 MW)
  - HVDC INGA – KOLWEZI 1700 km connection (560 MW present terminal stations; line built for 1150 MW)
  - INGA – KINSHASA - MALUKU 230 kV system

3.2 ***1974*: EdF** preliminary study of the hydroelectric development of Grand Inga (around 40,000 MW)

3.3 ***1982*: ENEL** (Mr. Corbellini, Prof. Paris: Italy-Africa conference) preliminary study for transfer to Europe up to 60,000 MW (see fig. 1)

3.4 ***1990*: ENEL** Direction of Strategies "The Grand Inga Project: the answer of Europe to environmental issues"

- 1st phase 15,000 MW only INGA
- 2nd phase 30,000 MW only INGA
- 3rd phase 60,000 MW INGA+PIOKA+MATADI

Transmission system development **in cooperation with ABB Sae-Sademi**. **Examined 4 line routes** (see fig. 2 and 3 Sae-Sadelmi report).

First phase (fig. 4): **15,000 MW** - **4 bipolar ±800 kV HVDC lines** (2 bipoles on route 2 and 1 bipole on route 1 and 3 as per fig. 2/3 - in alternative 2 bipoles on both routes 1 and 2).

Main economics in fig. 5.

3.5 ***1993-1996*: ABB Sae-Sadelmi pre-feasibility study**

- 3000-4500 MW from INGA Falls to South Africa; ±800 kV DC more convenient than ±600 kV DC (1997 Cigre Colloquium in South Africa see fig. 6). 3 routes examined. the best one from Inga to Alpha substation close to Johannesburg via Angola-Namibia and Botswana: 3000 km with cheap and simple guyed towers.

3.6 ***1997*: EdF – Lahmeyer:** report “Feasibility study: Egypt/DRC power system interconnection study”

- 4000-16000 MW in 4 phases with ±800 kV DC lines (see presentation of Lahmeyer).

1982 ENEL pre-feasibility study

Fig. 1

CORRIERE DELLA SERA

POSITIVO L'INCONTRO GOVERNO-SINDACATI

Accusa di «tentato omicidio aggravato» per il sacerdote aggressore del Papa

All'ONU si teme imminente lo sbarco nell'arcipelago

La Thatcher molto pessimista «Avvertimento» russo a Londra

Crack Sindona: verso il processo

Dall'Africa un «fiume» di elettricità

An ENEL futuristic project to convey energy to Europe.

A “river” of electricity from Africa.

1990 ENEL /ABB SAE-SADELMI

PRE-FEASIBILITY STUDY

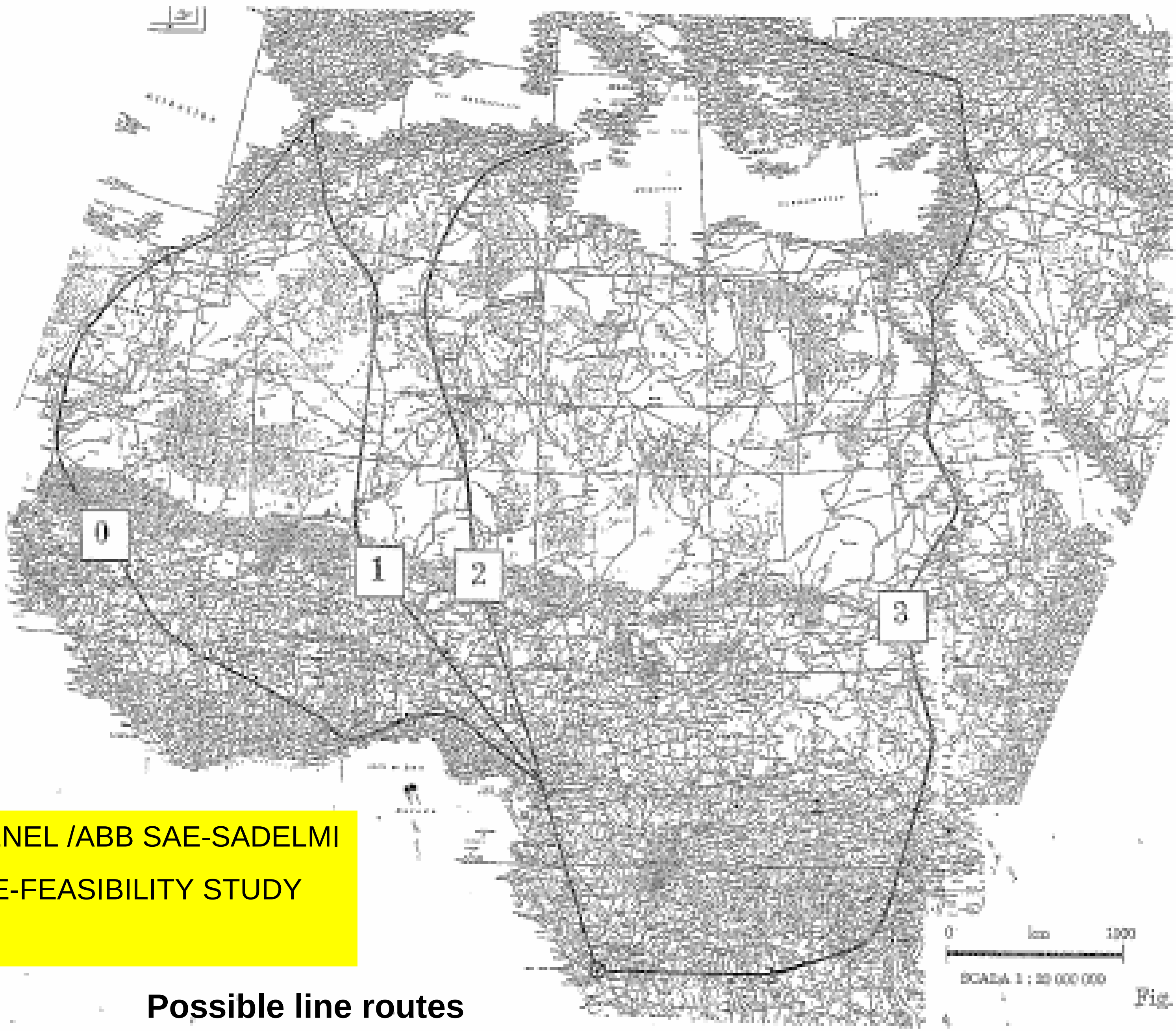


Fig. 2

Possible line routes

SAE SADELMI

1990 ENEL study

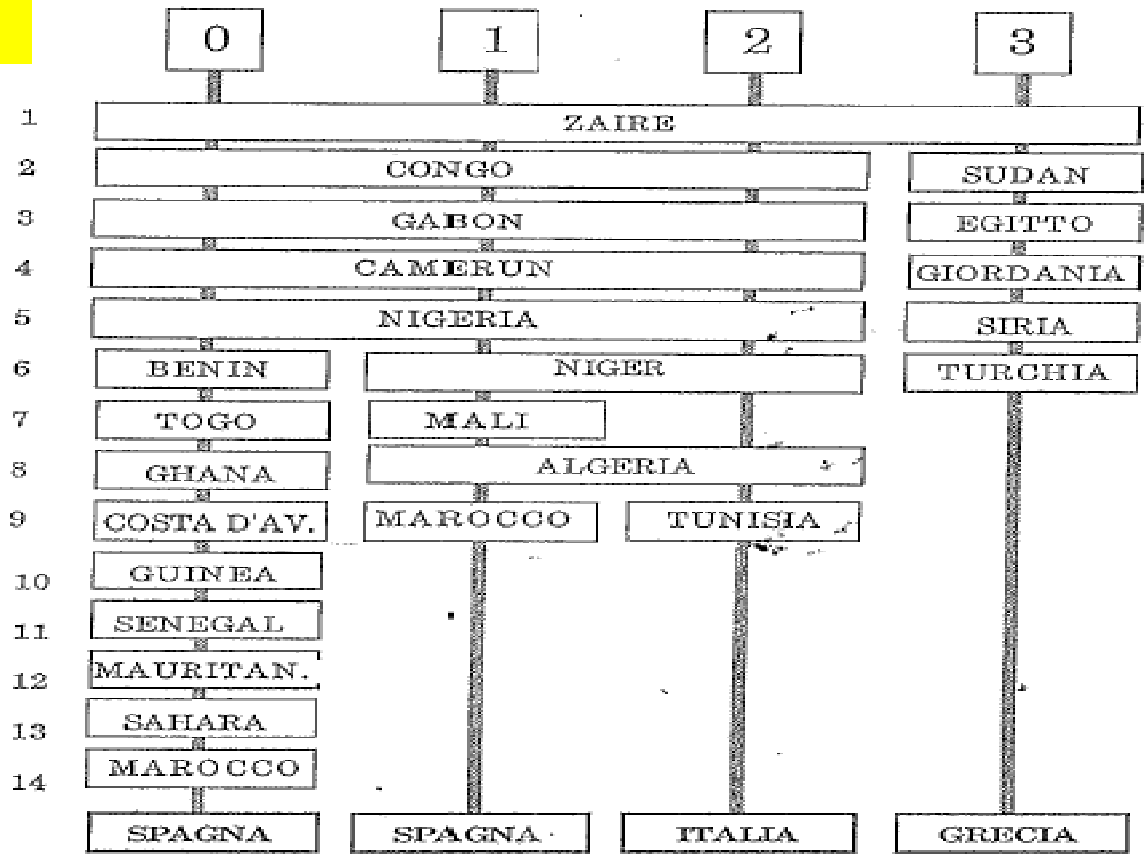
FIG. 3

TRASMISSIONE INGA-EUROPA

CARATTERISTICHE DEI TRACCIATI

Line routes

Crossed countries



LUNGHEZZA LINEE	km	7200	5200	5100	7400
DICUI NEL DESERTO	km	1200	1400	2000	1400
LUNGHEZZA CAVI	km	10	10	150	30

1990 ENEL Study First Phase

Fig. 4

Fig. 5

Economics for the Great Inga Project
(From ENEL Study in 1990)

1. Construction Cost for 15GW in Inga and 12GW in Europe

	Billion US$
Dam & Power Plant	15.0
HVDC Stations	2.2
OHTL's (4x3.5GW)	11.0
Submarine Cables	2.9
European Network Extention	1.2
Sub Total	32.3
Contingency (20%)	6.5
Total	38.8

Exchange rates average 1990: 1,190 italian lire = 1 US$

2. Conclusions

1) Not impossible technical difficulties.
2) Economic conditions are favorable: interesting cost for kWh in Europe.
3) Political situations could be an obstacle for transmission.

1993 ABB pre-feasibility study Inga - South Africa

Cigre Colloquium 1997 in South Africa

Fig.6

3000 - 4500MW FROM INGA FALLS (ZAIRE) TO SOUTH AFRICA WITH HVDC: A PRE-FEASIBILITY STUDY

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INTRODUCTION

Taking care the continuous improvements of HVDC technology and the possible increasing application to the transmission of large amount of power over long distances, in 1993 ABB performed a pre-feasibility study for an EHVDC line from the Inga Falls (Zaire) to the Republic of South Africa (RSA). The study was carried out on the basis of the terms of reference prepared by prof. Francesco Iliceto (Rome University, Italy), who originated the study. This paper provides a summary of both the main hypotheses considered and the main results got in the '93 study; even if some data on line and HVDC terminal costs may have changed in these four years with a better cost positioning of HVDC systems, the possible variations do not modify the conclusions. The same , applies to the new technology developments in HVDC substations [1].

Scope of the study was to provide initial technical and economical data useful for possible preliminary evaluations on the utilisation in South Africa of the cheap hydro electric power available in Inga (Zaire). In particular, the analyses were confined to a power in the range from 3000 to 4500 MW at sending end; the two voltage levels of ± 600 and ± 800 kV, close to the optimum one [2], were taken into account for this long transmission (3000-4000 km).

The cost of energy in Inga and the capital charge for transmission system investments were varied in a wide range to provide parametric results. Similarly, two different costs for reference transmission lines were envisaged.

The study considered only one bipolar line, while further analyses involving the effects on cost and reliability of separate monopolar lines in the same right of way (ROW), or in separate ROW's, are left to future studies.

For the transmission line routing and line reference costs, the experience in the region of ABB Feralin, an ABB South African subsidiary specialised in transmission lines, was availed. All the aspects related to HVDC terminal stations were studied with ABB Power Systems of Sweden; the ± 800 kV voltage level was considered feasible and available for the project under evaluation.

TRANSMISSION SYSTEM - MAIN TECHNICAL HYPOTHESES

- **Overhead DC (OHDC) lines**

In the first stage of the study three different routes were analysed. Route "A" starts from Inga and reaches the Hydra substation (S/S) in the Republic of South Africa (RSA) via Angola and Namibia and is 3500 km long, route "B" reaches the Alpha S/S in the RSA via Zambia, Zimbabwe and Botswana being 4000 km long, route "C" reaches the Alpha S/S in the RSA via Angola, Namibia and Botswana and is 3000 km long. A preliminary evaluation with Feralin brought, for this pre-feasibility study, to the choice of route "C" due to both the shorter length and the strategic power delivery point (Johannesburg).

According to ABB Feralin practice, guyed lattice towers were considered for a DC line having average spans of 400 m and maximum sags of 13 m (longer spans could be considered in future optimisation studies).

4. THE GRAND INGA - MAIN COMMENTS TO BE CONSIDER FOR FUTURE WORK

- Key issue for DRC and Africa is **a quick revamping** of the around 1750 MW of the **existing INGA 1 and INGA 2** power plants and a revamping/upgrading of the 1700 km **INGA-Kolwezi HVDC interconnection**; this is equivalent to a very cheap 1000 MW hydro power plant in Kolwezi to contribute to short term needs of the African market.

- **Grand Inga, the great opportunity for Africa** socio-economic-political **development/integration** through local renewable energy sources. A technological, financial, political challenge.

  Grand Inga implies **long range planning activities**; this considering the energy supply to/and engagements of local markets are for the **period 2020-2060** with long term commitments to be taken in 3-4 years from now. This **affects energy policies of all the involved countries.**

- **Modified market conditions in the last 10-15 years** (liberalization/privatization processes and a financial world always more eager for high/short returns on investments); to attract private investments, the project must have a **financial and political support of development banks/international institutions** for an **Africa renaissance**.

- **The sharp increase of some “prime materials” in the most recent years** (Cu, Al, steel, etc.) have strongly modified the infrastructure investments (increase by far exceeding inflation rate). On the other hand we have sharp increase of oil and gas prices + their security of supply+environmetal issues of generation from fossil fuels: **electricity from fossil fuels is going to become less and less competitive.**
- Considering the actual development stage of **INGA 3**, **the Grand Inga must be considered not as a competitor** but as a subsequent “integrator” of electric energy supply in the overall Africa. Grand Inga should be a pusher for a quick starting of INGA 3 and **INGA 3 should be the “reduced scale prototype” of the Grand Inga.** Grand Inga has however to be developed without spoiling other projects under consideration in Africa (Ethiopia, Angola, Cameroon, etc.)
- The portion of **investment cost + O&M costs + cost of losses of transmission** over ultra long distances (around 5000 km), becomes an **important portion of the delivered kWh cost;** the wheeling cost of kWh exceeds the generation cost.
- For a better chance of the Grand Inga success, it is fundamental to consider **close to INGA some energy intensive industries** (e.g. aluminum smelters, etc.) and why not production of H2 in the future to alleviate environmental impact of transports? Application of CdM mechanisms should be analyzed.

- **Transmission losses for long distances are in the range of 15-20%** and are affecting the actual delivered power capacity; how to evaluate them? Loss of revenues? Additional increase of capital investment? A simple energy formula or a binomial formula including a capacity payment added to actual losses?
- The investment cost of the power plant is proportional to peak power and the cost of kWh is inversely proportional to the hours of utilization of peak power; the cheapest kWh production cost is for plant working at peak load practically 100% of the time (base load plant).
- The **transmission cost will be strongly affected by (N-1) conditions**, if INGA has to be considered an "**energy low cost plant for base load**". The acceptability of monopolar operation with ground return of OHTL's (overhead transmission lines) can help to reduce transmission investments; with no monopolar operation at least in emergency conditions, additional circuits or an increased capacity for the considered ones must be taken into account.

- The possible **insulation of ±800 kV DC lines**, strongly affects their cost; special tests on some insulation strings properly energized along the different envisaged line routes (especially desert areas) must be considered during the feasibility study. This **to avoid** the negative effect **of redundant insulation** (increased cost with no return) **or** of **insufficient insulation** (very poor reliability and additional O&M costs for insulation cleaning). Possible extended use of composite insulators has to be analyzed.
- **The countries crossed by OHTL's** must be **duly involved** in the construction and O&M of the lines; they should get a "fee" proportional to the "kWh passing on the lines" to have their actual and continuous involvement on line availability and these fees must go even down to the local municipalities. Local supply of part o the energy crossing these countries becomes a political must
- Let me conclude on **Grand Inga for Africa** with a Latin adage: "**Per aspera ad astra"** (let us reach marvelous stars through difficult paths)…, but to be successful it is **essential the political will** of you **African countries**. Inga must be an African baby; WEC, the institutions can try to help/act as facilitators. The "conception", birth and growth of the baby, is your task and you all are the father and the mother for the benefit of African future generations and for their better life.