Minutes of Meeting

Fourth Ordinary Meeting of the Distribution and Commercialization Committee

Theme: Energy Distribution Investment and Loss Reduction Workshop

Abuja. 8 to 10 August, 2017
I. INTRODUCTION

1. The WAPP Secretariat with assistance from Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) undertook a Distribution Investment Development and Loss Reduction Program as part of the Programme "Promoting a climate-friendly interconnected power system in West Africa."

2. This Programme was sub-divided into the following:
   a. Assist ECOWAS Member Countries to implement the regional strategy of renewable energy relate to the electricity network.
   b. Assist in the design and construction of infrastructure for the production and transportation of renewable energy.
   c. Strengthen the capacity of the regional distribution center teams and the five (5) sub-regional centers to be able to manage dispatching and exchanges of electricity at the regional level.
   d. Reduce the loss of electrical energy.
   e. Strengthen the capacity of staff of ECOWAS electric power distribution companies.

3. The purpose of this sub-programme (2d above), which is the subject of a completed study is to propose solutions to reduce distribution system losses which are currently above acceptable limits.

4. The Consultant, GOPA-intec presented the final report on 14th and 15th of December, 2016 which was adopted by the participants during the 3rd meeting at Bingerville (Côte d'Ivoire) subject to incorporation of comments raise by participants.

5. The WAPP Secretariat in collaboration with GIZ and Abuja Electricity Distribution Company (AEDC), organized a meeting with the Distribution and Commercialization Committee from the 8th to 10th of August, 2017 at the AEDC Learning Center in Abuja for Anglophone Distribution utilities.

6. The objective of this Distribution and Commercialization Committee (DCC) meeting is to:
   a. adopt a harmonized methodology for the determination and calculation of distribution losses.
   b. adopt the proposed loss reduction programs and the various recommended strategies.
c. Create a framework for organizing regional forum for distribution Utilities to share best practices and attraction of funding from multilateral financial institution.

d. Adopt Key Performance Indicators (KPI) for the evaluation and monitoring of distribution losses.

e. Adopt tool box for loss reduction to be used in the presentation of bankable projects.

7. The adopted agenda is attached in Annex 1.

II. WELCOME AND OPENING ADDRESS

8. Introducing the meeting, the Head of Organization Development and Learning, Dr. Solomon Ilidero of AEDC welcomed all the participants and appreciated the honor given to AEDC to receive the WAPP family. He then thanked the WAPP and GIZ teams for choosing AEDC to host this important meeting and concluded by wishing the participants a successful deliberation.

9. Mr. Folorunsho Dada, the Head of Human Resources Development in AEDC who represented the MD/CEO of AEDC welcomed and addressed the participants and wished them a fruitful deliberation.

10. In his address, the Chairman of the workshop, Engr. Omolaolu Gabriel Olusesi welcomed all participants to the workshop. He also expressed appreciation to WAPP (Organizer) and GIZ (Sponsor) for undertaking loss studies and workshop. He added that, the health of any Enterprise is measured by the financial standing of the utility and no business can survive if the losses incurred are much more than the revenue realized. He spelt out that, the mission in this three-day-workshop among others will be to adopt:

- A harmonized methodology for the determination and calculation of distribution losses;
- Proposed loss reduction programs and various recommended strategies;
- Key Performance Indicators (KPI) for the evaluation and monitoring of distribution losses;
- Tool Box for loss reduction to be used in preparation of bankable projects and;
- Create a framework for organizing Regional Forum for Distribution Utilities aimed at sharing best practices and attraction of funding from multilateral financial institutions.
11. Speaking on behalf of the General Secretary of the WAPP, Mr. DIAW Oumar, Ag. Director of the Information & Coordination Center (ICC), thanked the Management and staff of Abuja Electric Distribution Company for their willingness to host this meeting and also the support that is always rendered to WAPP any time they are called upon. He also thanked the experts of the various electricity companies for participating in this three day meeting. Mr. Oumar stated that, GIZ has been supporting the WAPP Secretariat in a study of Distribution Losses in the networks of WAPP Distribution Utilities. This study was necessitated due to the desire of the WAPP Secretariat to improve the performance and financial viability of WAPP Distribution Utilities. Following the last meeting of the Distribution and Commercialization Committee in Abidjan, the WAPP Secretariat tasked the Consultant to develop a harmonized framework for the determination, calculation and categorization of the various forms of Distribution Losses as well as Monitoring and Evaluation (M&E) mechanisms to monitor and assess the performance of utilities in the area of distribution losses. He therefore concluded by wishing the participants a fruitful discussion.

12. The representative of the GIZ, Mr. BASILE-GBEDJI Armand Polycarpe, thanked Abuja Electricity Distribution Company and its staff for accepting to host the workshop. He also thanked all delegations who made it to Abuja to participate in this meeting.

13. Mr. BASILE-GBEDJI Armand Polycarpe noted that Since 2013, the German Government has set up a program entitled “Promotion of a climate-friendly interconnected power system in West Africa” in order to support the Economic Community of West African States (ECOWAS) and its specialized institutions which are, ECOWAS Regional Electricity Regulatory Authority (ERERA), ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREE) and the West African Power Pool (WAPP).

14. On this basis, a consultant was selected to investigate the high distribution losses in Utilities within the sub-region. The Consultant identified a total of ten (10) technical solutions and best practices and six (6) non-technical solutions some of which might not require large financial investment but rather corrections to be made in the operational activities.

15. Also, Mr. BASILE-GBEDJI mentioned that, in the next three years starting from 2018, a new program will be funded by the German Government for the benefit of the ECOWAS. This new program will include the following activities:

   a. Monitoring of the solutions to fight high distribution losses implemented by the electric power distributors in the region.

   b. The continuation of the strengthening of the capacity of ECOWAS electricity companies’ staff, to better manage power grids and to fight distribution losses.
c. The development of standards for medium and low voltage power lines, for WAPP electricity companies. These standards are to address the design, equipment mounting and protection standards for electric network equipment and maintenance standards.

d. Support the implementation of strategies for the strengthening and management of electricity distribution networks in ECOWAS countries in order to reduce distribution losses.

e. Finally, all the ECOWAS distribution companies will be assisted to revitalize their statistical services so as to have exhaustive and reliable technical data from their electricity grids by 2020.

16. The GIZ representative concluded by urging all participants to assist WAPP to achieve its set goals. He finally wished all of participant an excellent and fruitful discussions.

III. PARTICIPANTS

17. The following were present at the meeting:

- Representatives of the WAPP Secretariat
- The representative of GIZ,
- The following utilities:
  - Electricity Distribution and Supply Authority (EDSA) - Sierra Leone
  - Ibadan Electricity Distribution Company (IBEDC) - Nigeria
  - Enugu Electricity Distribution Company (EEDC) - Nigeria
  - Kano Electricity Distribution Company (KEDCO) - Nigeria
  - Association of Nigerian Electricity Distributors (ANED) - Nigeria
  - Abuja Electricity Distribution P.l.c (AEDC) - Nigeria
  - Kaduna Electricity Distribution Company (KAEDCO) - Nigeria
  - Northern Electricity Distribution Company (NEDCo) - Ghana
  - Electricity Company of Ghana (EGC) - Ghana
  - National Water and Electricity Company Ltd. (NAWEC) - The Gambia

18. See attached list of participants as Annex 2

IV. NOMINATION OF RAPPORTEURS

19. Under the chairmanship of Engr. Omolaolu Gabriel Olusesi (AEDC), the following participants were designated as rapporteurs:

- Mrs. Sanya Folasade (IBEDC),
- Mr. Tampuri Mohammed Tayeb (NEDCo).
V. RESULTS OF THE MEETING

A. PRESENTATIONS

20. The representative of WAPP made a presentation on the upcoming WAPP Energy Market that is under development. He emphasized on the need for an integrated energy pool in West Africa. A second presentation was also made by the WAPP secretariat on the outcomes of the Consultant’s report.

21. The participants from the various WAPP Distribution Companies made a 20 minutes presentation each on the state of the losses in their respective utilities. Each presentation covered a brief of the following:

a) Network infrastructure
b) Distribution losses separated into Technical and Non-technical losses
c) Revenue collection rate
d) Causes of high Technical and non-Technical losses
e) Actions to reduce High Technical and non-technical losses
f) Methodology for the determination of Technical and non-technical losses
g) Target Key performance indicators
h) Monitoring and evaluation of Losses
i) Electricity access rate

B. GROUP DISCUSSIONS

22. On the second day of the meeting, the participants were divided into sub-groups to undertake the following tasks:
   - GROUP 1: Develop framework for the evaluation of energy losses and develop a harmonized measurement methodology;
   - GROUP 2: Create a framework for organizing Regional Forum for Distribution Utilities;
   - GROUP 3: Technical section of toolboxes.

Each group made a presentation on the outcomes of their deliberations to the Committee.

B1. GROUP 1: Develop framework for the evaluation of Energy losses and Electricity access and develop a harmonized measurement

23. Group 1 reviewed the Methodology for the computation of Technical losses proposed by the Consultant (GOPA-intec). It was agreed that, the consultant’s methodology was ideal for the determination of losses but required a lot of Data input for a long period of time. However, most of the Discos in the ECOWAS region do not have the required infrastructure to collect such data. Hence, a simplified methodology was adopted for the determination of losses in the distribution system.

24. Three key performance indicators were identifies for the member utilities. These are:
   - KPI 1: Global (Total) Losses
• KPI 2: Technical Losses
• KPI 3: Non-technical Losses

25. The working group has also agreed to monitor the collection rate as another indicator.
• KPI 4: Revenue collection rate

26. Attached is Annex 3 showing the adopted methodology for loss computation.

B2. GROUP 2: Create a framework for organizing Regional Forum for Distribution Utilities

27. Group 2 was required to Create a framework for organizing Regional Forum for Distribution Utilities. An outline was developed for the West Africa Power Distribution Utilities Forum (WAPDUF). The framework is aimed at:

• Exchange best practices in the field of reduction of distribution losses
• Train the players of the sector for better performance
• Communication with partners (supplier, subscribers, authority)
• Exchange best practices at work

28. To achieve the objectives, the following themes were adopted;
• Theme A: Improve revenue collection rate
• Theme B: Non-Technical losses reduction
• Theme C: Technical losses reduction
• Theme D: Actions for the implementation of environmental aspect
• Theme E: Action related to customer needs

29. The forum targets power distribution utilities, consumers' representatives, industries, material suppliers and authorities.

30. The timelines for the meeting was agreed to be once in a year in any selected member country.

31. Annex 4 shows the detail outlines developed for the forum.

B3. GROUP 3: Technical Section of Toolboxes

32. GROUP 3 was required to review and adopt the financial and investment proposal requirements for the member countries to access funding from donors. The group developed a template for presenting loss reduction projects to donors for funding.

33. It was agreed that, each member utility will adopt the template in presenting at least three (3) projects on loss reduction to the Donor by end of September 2017.

34. Annex 5 shows the template and guidelines for the submission of loss reduction projects.
VI. RECOMMENDATIONS

35. The participants recommend that the WAPP Secretariat present to the board for adoption and implementation of the following:

35.1 The methodology developed for the computation of losses
35.2 The Outline for the West African Power Distribution Utilities Forum (WAPDUF)
35.3 Template for the presentation of Loss reduction project to Donors for funding.

36. The WAPP secretariat should organize a donor conference by October, 2017.
37. The first WAPDUF meeting should be held in Sierra Leone by November, 2017.
38. WAPP should support the DISCOs to acquire the needed software for performing losses studies.
39. Each utility should submit at least three (3) loss reduction projects not later than September 30, 2017 to WAPP.

VII. ACKNOWLEDGMENTS

The participants express their sincere gratitude to the People and Government of the Republic of Nigeria, particularly to His Excellency Muhammad Buhari, President of the Republic of Nigeria, for their warm welcome during their stay in Abuja.

The participants also thank the Managing Director and staff of AEDC for the facilities placed at their disposal to guarantee the success of the meeting.

Prepared at Abuja, this 10th day of August 10, 2017

For
WAPP secretariat
Mr. Oumar DIAW
AG. Director of ICC /WAPP

Workshop Chairman
Engr. Omolaolu G. O
Head Protection, Communication and Metering/ AEDC

SIGNATURE

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Annex 1
### DRAFT AGENDA

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<tr>
<th>Time</th>
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<td><strong>DAY 1: 8 AUGUST, 2017</strong></td>
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<td>8:30 – 9:00</td>
<td>Arrival and Installation of participants</td>
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<td>8:45 – 9:30</td>
<td><strong>OPENING CEREMONY</strong></td>
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<td>Welcome address</td>
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<td>Group photo</td>
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<td>9:30 – 10:00</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>10:00 – 10:15</td>
<td>• Appointment of the chairman and rapporteurs</td>
<td>Participants</td>
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<td>• Review and adoption of the agenda</td>
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<td>10:15 - 11:00</td>
<td><strong>PRESENTATION SECTION</strong></td>
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<tr>
<td>10:15 - 11:00</td>
<td>Overview on the study relating to the distribution investment and Loss reduction (Gopa-Intec Report and recommendations)</td>
<td>Representative, WAPP and GIZ</td>
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### DAY 1

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<td>11:00-13:00</td>
<td>Presentation by each company of the activities they implemented to reduce distribution losses and energy savings: 1. Abuja EDC, 2. ANED, 3. NEDCO, 4. KAEDC, 5. Eko EDC, 6. Kano EDC.</td>
<td>Discos’ Representative (20mn/Disco)</td>
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<td>13:00-14:00</td>
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<td>14:00-17:00</td>
<td>Presentation by Distribution Companies (continued)</td>
<td>Discos’ Representative (20mn/Disco)</td>
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<td><strong>WORKING GROUP SECTION</strong></td>
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<td>09:00–10:30</td>
<td>Work in three sub-groups on the following points: 1. Develop framework for evaluation of Energy Losses, and Electricity Access and develop harmonized measurement; 2. Develop outline for Distribution Energy Efficiency Program (DEEP) similar to CLUB-ER; 3. Technical Section of Toolboxes;</td>
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<td>13:00-14:00</td>
<td>Lunch break</td>
<td>Rapporteurs of subgroups 20 mn/subgroup</td>
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### Activities

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<td>Synthesis of the work results</td>
<td>Chairman of the workshop</td>
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### DAY 3 : 10 AUGUST, 2017

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<td><strong>PREPARATION &amp; VALIDATION OF THE AIDE MEMOIRE</strong></td>
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<td>Preparation of the Aide Memoire</td>
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<td><strong>PRESENTATION AND POOLING OF SUB-GROUP WORKS</strong></td>
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<td>Presentation and Validation of the Aide Memoire</td>
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<td>17:00– 17:30</td>
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**ATTENDANCE LIST**

**Abuja, 8 - 10 August, 2017**

ENERGY DISTRIBUTION INVESTMENT AND LOSS REDUCTION WORKSHOP
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<td>Billing Assistant</td>
<td>rizkya.igowappporte@</td>
<td>+229 97 05 63 88</td>
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<tr>
<td>Casmi Che Di</td>
<td>Accountant</td>
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<td>She KAM</td>
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**Signature:**
Annex 3
framework for the evaluation of Energy losses and Electricity access and develop a harmonized measurement
Methodology for the Evaluation of Technical Losses

Calculation of Distribution losses involved subtraction of energy billed for all customer classes from the energy purchased/injected into the network. Distribution losses comprise of technical and non-technical losses. Technical losses can be estimated using load flow simulations. The difference between distribution losses and the estimated technical losses gives the non-technical losses.

The following methodology has been proposed for the estimation of technical losses in the various sections of the distribution network, sub-transmission and power transformers, medium voltage, distribution transformers and low voltage (LV) network.

1) Sub-transmission and Power Transformers

i. Model the entire sub-transmission network with the power transformers. Lump the load of each primary substation at the secondary side of the power transformer.

ii. Determine the peak demand \( PD_{ST} \) and compute the load factor of each sub-transmission feeder.

iii. Run load flow simulation each sub-transmission to obtain the sub-transmission feeder losses as \( PL_{ST} \) in kW.

iv. Compute the energy losses for each Sub-transmission feeder as \( PL_{ST} \times \text{Loss Load Factor (LLF)} \times 8760 \) in kWh.

v. Compute the energy injected into each sub-transmission feeder as \( PD_{ST} \times \text{load factor} \times 8760 \).

vi. The percentage sub-transmission feeder energy losses \( \%E_{STF} \) is computed as the ratio of the sum of sub-transmission feeder energy loss to the energy input expressed as a percentage.

vii. Estimate the load and no-load losses of the power transformers using transformer manufacturer data/specification in kW \( TL_{P} \).

viii. For no-load losses estimation, use the total no-load loss figure as stated by the manufacture/specification per transformer.

ix. For load loss, estimate based on the loading of the power transformers.

x. Power transformer losses \( \%E_{PT} \) is ratio of power transformer energy losses to the energy through the power transformer expressed as percentage.

2) Medium Voltage (MV)

\[ LLF = (LF \times a) + (LF^2 \times (1-a)) \] empirical factor a is selected based on historical load profiles.

\[ 8,760 \] is the number of hours in a year
i. Sample 10% of the medium voltage feeders in the various business units of the Distribution Company according to the loading of the feeders, high, medium and low.

ii. Determine the peak demand $PD_{MV}$ and compute the load factor of each MV feeder.

iii. Run load flow simulation for each of the selected medium voltage feeders to obtain the medium voltage feeder losses ($PL_{MV1,...,MVn}$).

iv. Compute energy loss for each MV feeder as $PL_{MV} \times \text{Loss Load Factor (LLF)} \times 8,760$

v. Compute energy input into each MV feeder as $PD_{MV} \times \text{Load Factor} \times 8,760$

vi. The percentage MV energy loss ($%EL_{MV}$) is computed as the ratio of the sum of MV feeder energy loss to energy input expressed as a percentage.

3) Distribution Transformers

i. Estimate the load and no-load losses of the distribution transformers using transformer manufacturer data or specification in kW ($TL_{DT}$)

ii. For no-load losses estimation, use the total no-load losses figure as stated by the manufacture per transformer.

iii. For load loss, estimate based on the loading of the distribution transformers.

iv. Distribution transformer losses ($%E_{DT}$) is ratio of the distribution transformer energy losses to the energy through the power transformer expressed as percentage.

4) Low Voltage Network (LV)

i. From each sampled MV feeder, further sample 5% of the distribution transformers connected to that feeder based on their loading, high, medium and low.

ii. Model all outgoing LV circuits emanating from each selected distribution substations (conductor size, type and length)

iii. Using a power quality analyzer, measure the loading and power factor for each of the selected LV circuits for a period of seven (7) days, capturing weekday and weekend load readings.

iv. Determine the peak demand ($PD_{LV}$) within the period and compute the load factor of each LV circuit.

v. Run load flow simulation for each of the selected LV feeders to obtain the LV feeder losses ($PL_{LV1,...,LVn}$).

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3 For small networks with updated network diagrams, run simulation for the entire medium voltage network
vi. Compute energy loss for each LV feeder as $PL_{LV} \times \text{Loss Load Factor (LLF)} \times 8,760$

vii. Compute energy input into each LV feeder as $PD_{LV} \times \text{Load Factor} \times 8,760$

viii. The percentage LV energy loss ($\%EL_{LV}$) is computed as the ratio of the sum of the LV feeder energy loss to energy input expressed as a percentage.

The total percentage technical energy losses is computed as the sum of percentage energy losses in the Sub-transmission feeder network ($\%E_{STF}$), Power transformers ($\%E_{PT}$), Medium Voltage network ($\%E_{MV}$), Distribution transformers ($\%E_{DT}$) and the Low Voltage network ($\%E_{LV}$).
1. Task 2: Quantification of losses in the power distribution networks

1.1 Definition of technical terms

Distribution network

These are the networks whose isolation level is less than or equal to 45 kV. In some countries, however, some 30 and 33 kV lines are considered as transmission lines.

Total energy losses \( (P_{GE}) \)

This is the difference between the energy injected into the distribution network \( (E_i) \) and that consumed by the users \( (E_C) \).

\[
P_{GE} = E_i - E_C
\]

Energy injected into the MV distribution network \( (E_{IMT}) \)

The energy injected into the MV distribution network \( (E_{IMT}) \) is calculated by summing the energy of all HV/MV \( (E_{PS}) \) substations and all energy generation plants \( (E_{PRMT}) \) which are injected directly into the MV distribution network. There is therefore the following relation:

\[
E_{IMT} = \sum E_{PS} + \sum E_{PRMT}
\]

Energy injected into the LV distribution network \( (E_{IBT}) \)
The energy injected into the LV distribution network \( (E_{IBT}) \) is calculated by summing the energies injected by the MV/LV substations \( (E_{PMTBT}) \) and, where applicable, those injected by the generation plants which are injected directly into the LV connections \( (E_{PRMT}) \) to the MV/LV distribution substations.

\[
E_{IBT} = \sum E_{PMTBT} + \sum E_{PRBT}
\]

Energy injected into the distribution network \( (E_j) \)

Energy injected into the distribution network is the sum of the total energy injected into the MV distribution network \( (E_{IMT}) \) and that injected by the plants flowing directly into the LV network \( (E_{PRBT}) \).

\[
E_j = E_{IMT} + \sum E_{PRBT}
\]

It should be noted that the energy injected by the MV/LV substations in the LV network is already included in \( E_{IMT} \) and should therefore not be taken into account in the calculation of \( E_j \), otherwise it will be counted twice.

Energy consumed by the users

It is the sum of the energy consumed by the users of the MV network and the users of the LV network.

Energy consumed by the users of the MV network

It is the sum of the energy consumed by:

- MV consumers;
- Internal MV consumers (these include water pumping stations for companies in charge of the treatment/distribution of water);
- MV fraudsters (not measurable by definition)
**Energy consumed by LV network consumers**

It is the sum of the energy consumed by:

- LV consumers;
- Internal LV consumers;
- LV fraudsters (not measurable by definition).

**Total energy losses rate (T_{PG})**

This is the rate expressed as a percentage calculated from the value of the total losses in relation to the energy injected into the distribution network.

\[ T_{PG} = \frac{P_{GE}}{E_t} \times 100 \]

**Technical energy losses (P_{TE})**

It is the energy lost due to physical phenomena inherent in its transport between the substations or the generation plants, when these directly inject the energy produced into the distribution network and the metering points at the level of the subscribers.

These losses are estimated by performing simulations using load distribution calculation software for several load stages defined from a typical load curve.

**Technical power losses (P_{TP})**
These are the instantaneous losses caused by the power transmitted in installations such as conductor cables of LV and MV lines but also in the LV/MV transformers.

Non-technical energy losses \((P_{NTE})\)

It is the difference between the total losses and the technical losses.

\[
P_{NTE} = P_{GE} - P_{TE}
\]

These losses originate from fraudulent acts (by-passing the meter, clandestine connections, etc.), malfunctions of equipment (meters, billing software, etc.) and various errors such as estimation of consumption of flat-rate consumers, the omission of the specific consumption of the distribution company in the static consumption, etc.)

Collection losses \(P_E\)

Collection losses represent the difference between the amounts billed to consumers \((M_F)\) and the amounts actually collected by the operator \((M_P)\) expressed in monetary unit.

\[
P_E = M_F - M_P
\]

1.2 Standard calculation model of technical losses in the distribution networks

This study has shown that distribution companies generally do not have all the information necessary to calculate technical losses using a single method.
The distribution companies were therefore grouped according to the similarity of the information they were able to provide. For each group of companies, the Consultant has developed a technical loss assessment methodology adapted to the information available.

Nevertheless, in order to allow future comparisons to be made of the distribution losses of the WAPP distribution companies, GIZ has requested the Consultant to propose a standard methodology that would allow companies to evaluate technical losses on the same basis.

To do this, the method should be as simple as possible and take into account the information that is most often available. Companies must, however, make the necessary arrangements to collect the minimum information required for the application of the proposed method.

Depending on the degree of knowledge of the distribution network, it will be possible to evaluate the technical losses on the entire distribution network or it will be necessary to make calculations only on the most representative samples of the networks and extrapolate the results over the entire distribution network.

However, the principle of estimating technical losses is the same; either it is carried out on the entire distribution networks or on samples.

To illustrate this principle, an estimate of the technical losses on a sample of a distribution network is shown below.

Since there are non-technical losses both on the MV and LV networks, in order to distinguish between these two levels of losses, it is also necessary to estimate the technical losses separately for these two types of networks.

### 1.2.1 MV networks

For MV networks, the calculation of technical power losses is carried out by performing load distribution simulations on the MV feeders.

To do this, it is essential to know the topology of the MV feeders studied. This topology allows the development of single-line diagrams specifying the type and cross-section of the cables as well as the
length of each line section of an MV connection. Today, the topology of electrical networks is digitalised using Geographic Information System (GIS).

The studied MV feeders are then modeled using load distribution calculation software (NEPLAN, PowerFactory or equivalent).

The technical power losses are then calculated as described below.

The power injected into the MV feeders is a function of the load demanded by the MV / LV distribution substations, but this load varies considerably during the day, as illustrated in the following figure.

**Figure 1:** Daily load curve

![Daily load curve](image)

The load also varies according to the days of the week. Indeed, the load curves are generally different depending on either it is a working day, a Saturday, a Sunday or a public holiday. Finally, the load also varies according to the season.
Since power losses vary considerably depending on the square of the load, several simulations should be made to consider for the change in losses over the time.

In order to integrate the daily, weekly and seasonal variations in the simulations, these must be performed on the basis of annual load curves with an hourly resolution.

The following illustration shows the appearance of a typical annual load curve based on the hourly loading points.

**Figure 2: Annual load curve**

From the load curve, a curve representing the hourly loads classified according to their amplitude can be created. This curve is called annual load duration curve which is illustrated in the following figure.
In order to calculate the losses, it would in principle be possible to carry out load distribution simulations for all available values, i.e. 8,760 simulations.

For reasons of simplification and standardization of the calculation method, it is proposed to define four constant load steps such that the sum of the surfaces of the four rectangles formed by these steps is substantially equal to that defined under the duration curve. Given the typical shape of the annual load duration curve, these steps are defined on the basis of the following time intervals:

- Step n° 1 : $0 \, h < T \leq 1.000 \, h$
- Step n° 2 : $1.001 \, h < T \leq 4.500 \, h$
- Step n° 3 : $4.501 \, h < T \leq 8.000 \, h$
- Step n° 4 : $8.001 \, h < T \leq 8.760 \, h$

The value of each level is calculated by arithmetically averaging the loads of the load duration curve over the time interval corresponding to such step. The definition of the load steps is illustrated in the following figure.
The technical power losses are then calculated using the load distribution software for each one of these four load steps.

Finally, for the same reasons of standardization and simplification, it is proposed to consider that the power injected into the MV feeders is distributed over each MV/LV distribution substation fed by the respective connections in proportion to the nominal power of the transformers equipping MV/LV substations.

The annual technical energy losses on the MV feeders are then calculated by summing the yields of the power losses of each step by the corresponding time interval.

\[ p_{TAEN} = \sum_{i=1}^{4} p_{PUi} \cdot t_i \]
with \[ p_{TAEN} = \text{Annual technical energy losses} \]
\[ p_{PUi} = \text{Power losses of the load step } i \]
\[ t_i = \text{Load time interval } i \]

Since all the MV feeders of the distribution network are digitalised and the information concerning the time capacities injected into the MV feeders is known, the calculation can be carried out for the entire MV network.

### 1.2.2 LV networks

In order to estimate the technical losses in LV networks, it is essential to perform load distribution simulations. It is, therefore, necessary to have the topology of LV connections to be studied.

However, it is unthinkable for cost reasons to install equipment to record the power injected into the different LV connections of MV/LV distribution substations required by every LV consumer. The proposed method for estimating technical losses in the LV distribution network is based on the following simplifying assumptions:

- The power injected into the LV connections is calculated based on the same load curves and, therefore, on the same load steps as those defined for the MV feeders which feed them;
- The loads are uniformly distributed along the LV lines by considering intervals between the loading points of about 100 m.

The simulations result in power losses that are caused by the power transited for each load step. The annual energy losses are then calculated in the same way as for the MV networks, that is to say, by using the following relation.

\[ p_{TAEN} = \sum_{i=1}^{n} p_{PUi} \cdot t_i \]

\[ \text{Avec} \quad p_{TAEN} = \text{Annual technical energy losses} \]
\[ p_{PUi} = \text{Power losses of the load step } i \]
\[ t_i = \text{Load time interval } i \]
\[ n = \text{Number of load steps} \]

For companies which do not yet have LV network plans, it is necessary to carry out a survey on network samples in order to obtain a rough estimation of the variation range of these technical losses.

### 1.3 Proposal for a monitoring system

#### 1.3.1 Objective

The main objective of monitoring is to assess the distribution company's performance in reducing distribution losses and recognise the main reasons for the success or failure of the actions that have been undertaken.

#### 1.3.2 Procedures

The change in losses will be based on statistics of (i) consumption and (ii) energy injected into the distribution network. The companies will be required to submit the statistics covering the previous calendar year to the WAPP, once a year and at the latest on a date to be agreed.

In addition, distribution companies will be requested to provide the WAPP, at the same time, with the following information:

- A description of the actions taken during the previous year in order to reduce technical losses and non-technical losses;
- A qualitative estimation of the effectiveness of these measures.

#### 1.3.3 Calculation method of global losses on the distribution network

The global losses on the distribution network are in principle relatively simple to calculate. It consists in subtracting the total energy billed to MV and LV consumers from the total energy injected into the LV and MV distribution network.
With regard to the energy injected into the distribution network, this is calculated by summing the energies injected by the substations and the power plants flowing into the distribution network (MV and LV). The injection points within the distribution network of the substations and power plants are normally equipped with meters and the values recorded are usually transmitted to the statistics department of the distribution companies.

Concerning the energy billed to LV and MV consumers, the distribution companies, which carry out a systematic computation of the delivered energy, have this information. It is often centralised in the statistics or accounting department.

However, for companies which use flat rates billing, this information is not available. Indeed, these consumers have a connection whose power is theoretically limited by a fuse or a circuit-breaker to a value corresponding to the power subscribed. Nevertheless, the power demanded by consumers varies over time and the exact consumption of these consumers can only be estimated roughly.

Moreover, this type of connection is unfortunately the source of numerous frauds. Indeed, since there is no meter, there is no need to make readings. The integrity of the connection is therefore not subject to a regular visual inspection of the state of the fuses or of the circuit-breaker limiting the power demanded by flat-rate consumers. Some malicious consumers bypass the fuses or the circuit breaker, enabling them to consume power well beyond the contractual limit, or even supply electricity to the vicinity.

For these companies it is therefore impossible to know the real value of the energy consumed by the users in order to allow a correct calculation of the global losses on the distribution network.

### 1.3.4 Calculation method of the energy injected into the distribution network

Since there may be both non-technical losses at LV and MV levels and these are not directly quantifiable, it is necessary to distinguish the energy losses on these two networks. It is therefore also necessary to distinguish the total energy injected into the MV distribution network ($E_{IMT}$) from that injected into the LV network ($E_{IBT}$).

The energy injected into the MV distribution network ($E_{IMT}$) is calculated by summing the energy on all HV/MV ($E_{PS}$) substations and all generation plants ($E_{PRMT}$) which are injected directly into the MV distribution network. There is hence the following relation:
The energy injected into the LV distribution network \( (E_{IBT}) \) is calculated by summing the energies injected by the MV/LV substations \( (E_{PMTBT}) \) and, where applicable, those injected by the generation plants which inject directly into the LV \( (E_{PRMT}) \) connections from MV/LV substations.

For the LV network, there is the following relation:

\[
E_{IBT} = \sum E_{PMTBT} + \sum E_{PRBT}
\]

1.3.5 Calculation method of technical losses

These losses are to be calculated according to the method described in the previous chapter.

Since none of the MV feeders of the distribution network is digitalised and the information on the hourly power injected into the MV feeders is not known, the calculation of the technical losses in MV must at least be carried out for 2 heavily loaded MV feeders and 2 lightly loaded, in order to obtain at least a rough approximation of the range in which the technical losses change.

For companies which do not yet have LV network plans, it is necessary to record them on typical network samples in order to obtain a rough estimate of the range in which these technical losses evolve.

1.3.6 Estimation of the non-technical losses in energy

1.3.6.1 MV network

If the energy injected in the MV/LV substations is accounted \( (E_{IDMT}) \), it is possible to assess the non-technical losses in energy on the MV connection \( (p_{NTDMT}) \) by subtracting some energy injected in the MV connection \( (E_{IDMT}) \), energy injected in MV/LV substations \( (E_{IPD}) \) and the technical losses in energy on the MV connection \( (p_{TDMT}) \).
\[ P_{\text{NTDMT}} = E_{\text{IDMT}} - E_{\text{IPD}} - P_{\text{TDPMT}} \]

with

\[ E_{\text{IPD}} = \sum_{i=1}^{n} E_{\text{IPD}_i} \]

and \( n \) = number of MV/LV substations on the connection.

If the energy injected in the MV/LV substations is not accounted but the injected energy in the LV connection is accounted, it is possible to assess the energy injected in the MV/LV substations by adding the injected energies in the LV connections of the MV/LV substations and by adding the estimated value of the losses in the MV/LV transformers.

If the energy injected in LV connections is also not measured, it will be evaluated by considering the capacity range calculated from the power calculated based on the prorata of the installed capacity of LV/MV transformers.

The value of non-technical losses in energy on the MV distribution network \((P_{\text{NTMT}})\) is then calculated by summing the non-technical energy losses evaluated for each MV feeder.

Finally, it should be noted that the own consumption of distribution companies does not constitute losses, strictly speaking. This consumption must therefore be deducted from non-technical losses. For example, it concerns the MV consumption of administrative buildings of the company and the MV consumption of pumping stations, when the electricity distribution company also produces and distributes water.

1.3.6.2 LV network

Non-technical energy losses on the distribution network \((P_{\text{NTBT}})\) are calculated by differentiating between the energy injected in the LV network and the energy billed to LV subscribers.

Again, it should be noted that the own consumption of distribution companies on the LV network should be deducted from non-technical losses.
1.3.7 Recommendations for the monitoring of the WAPP distribution companies

As emphasized in our report, the non-technical losses on the LV network are the most important. It is therefore at this level that the priority should be given.

In order to identify rapidly the network parts causing high non-technical losses, the following information need to be obtained:

- Value in the injected energy in each LV feeders of the MV/LV substations
- Value in the injected energy by the plants directly debiting on each LV feeder
- Link between the consumers and the MV/LV substations or better, the LV feeder from which they are feeded.
- Metering the energy used by the consumers.

Unfortunately, these pieces of information are only very seldom available together. However, actions to be undertaken for the collection of the above listed information are quite easy to implement and are affordable and their profitability has been illustrated many times over.

The most important action is naturally to remove the contract subscriptions and to replace them by contracts based on appropriate postpayment or prepayment.
Annex 4
ECOWAS Countries Distribution Utilities’ Forum
Summary

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5. Organization ......................................................................................................... 5
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10. Evaluation/Tracking Results ............................................................................. 8
2. Background

The West African Power Pool is an ECOWAS Specialized Institution. Its objective is to integrate the operations of national power systems into a unified regional power market with the view to ensuring, in a medium and long terms, a reliable and regular power supply, at affordable costs to ECOWAS Member States. To this end, the institution works to ensure the coordination of power exchanges among ECOWAS Member Countries, as well as fostering and developing power generation and transmission facilities.

In order to promote wide access to energy for the people of ECOWAS Member Countries, the WAPP General Secretariat, with assistance from GIZ implements the “West African Climate-friendly Interconnected Power Systems Promotion” Program. This program is broken down into five sub-programs as follows:

a. Helping ECOWAS member countries with implementing the regional strategy for mater related renewables energies;

b. Helping them get studies carried out and construction works facilities achieved for the generation and transmission of renewables;

c. Building capacity for the Regional Dispatching Center Teams and the five (5) sub-regional centers to allow them handle the dispatching center and power exchanges at the regional level;

d. Mitigating power losses and,

e. Building capacity for ECOWAS Distribution Utilities’ staff.

The sub-program (d) was subject of a special study carried out by the GOPA-Intec Consultant, with the objective of proposing to the various distribution utilities, solutions for losses reductions which are actually outside acceptable range.

The Final Report for the study was presented from 14 to 15, December 2016, at the Conference room of the <<Centre des Métiers de l’Electricité (CME) in Bingerville, (Côte d’Ivoire)>> during the Third Meeting of the WAPP Distribution and Commercialization Committee (CDC).

The study took stock of the progress in the various losses reported and, proposed solutions to Distribution Utilities for the reduction of distribution losses as well as an investment program likely to contribute substantially to the reduction of distribution losses.

At the end of the meeting, the participants recommended the following:
- The organization of missions of experiences sharing between distribution utilities in the field of the reduction of distribution losses;
- The organization of a mission of exchange with the Rural Electrification Agencies’ Club to get information on its mode of operation and its experience in order to draw inspiration from it and, set up a trading platform dedicated to reduction of distribution losses;
- The implementation of a forum for power distribution utilities so that they can exchange best practices and agree on distribution losses standards;
- The implementation of recommendations of the study.

3. Objectives

The **West African Power Distribution Utilities Forum** (WAPDUF) is a meeting of power distribution utilities aiming at establishing an exchange framework among WAPP Member Utilities.

This framework will help the utilities:

- Exchange best practices in the field of reduction of distribution losses;
- Train the players of the sector for better performance;
- Communicate with partners (suppliers, subscribers, authorities...)
- Exchange best practices at work.

‘WAPDUF’ accompanies the WAPP Distribution and Commercialization Committee (DCC) to which it can make recommendations.

The forum seeks to be a melting pot for the dissemination of the knowledge and experiences of the various power distribution utilities fighting against distribution losses.

The forum will be held once a year in one of the utilities countries.

To achieve its objectives, WAPDUF opts for assisting one another to find possible solutions for information and good practices sharing in the following areas:

Theme A. Reduction in collection losses  
Theme B. Non-technical losses reductions  
Theme C. Technical losses reductions  
Theme D. Actions for the implementation of environmental aspects  
Theme E. Actions relating to customer needs

WAPP encourages the establishment of ECOWAS Member Distribution Utilities’ Forum to foster experiences sharing among distribution utilities and communicate with Financial and Technical Partners.
4. Forum’s target

- Power distribution utilities,
- Consumers’ representatives (according to the fields of activity)
- Industrials
- Material suppliers
- Authorities

5. Organization

WADUF consists of:

The Chairman of the Organizing Committee: He is appointed among the focal points for a period of one year

The Members of the Steering Committee: The four members of WAPDUF Steering Committee are designated among the focal points for a period of one year and oversee the search for facilitators for the selected themes.

The Focal Points: Each power distribution utility designates a focal point that will be WAPDUF Member.

The Secretariat: WAPDUF Secretariat is provided by WAPDUF Information and Coordination Center.

6. Communication

— Solicit stakeholder input.
— Listen to customer and trade ally need.
— Use utility channels and brands.
— Promote both energy and non-energy (e.g., improved comfort, improved air quality) benefits of energy efficient products and practices to customers.
— Coordinate with other utilities and third-party program administrators.
— Keep participation simple.

7. Activities

WADUF activities are organized around the following themes:

Theme A. Reduction in cash collection losses

Theme B. Non-technical losses reductions

Theme C. Technical losses reductions
Theme D. Actions for the implementation of environmental aspects

Theme E: Energy Efficiency (controlling one’s consumption)

Theme F: Renewable Energy (solar, wind...)

Theme: Troubleshooting

Theme: Public lighting

Theme: Access to Electricity

Theme: Losses reduction for bad power factor

Theme: Power security, sinister

Theme: Power equipment

Theme: Industrial maintenance

Theme: Indoor installation

Theme: Enforcement of standard specification

Etc.

WADUF activities are organized around the themes (non-limited) above and aim at strengthening the capacities of the experts of power distribution utilities, partners to multiply horizontal and vertical trade opportunities.

These exchanges concern all categories of agents and all fields of activities of the distribution utilities (technical, financial, administrative, management agents, etc.)

WADUF encourages work in immersion between distribution utilities to facilitate a better understanding of the concepts through direct and in-depth exchanges.
8. Members

The ECOWAS Countries Distribution Utilities’ Forum is composed of the following utilities:

<table>
<thead>
<tr>
<th>Power Distribution Utility</th>
<th>Country</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abuja Electricity Distribution Plc (AEDC)</td>
<td>NIGERIA</td>
<td></td>
</tr>
<tr>
<td>Benin Electricity Distribution Company (BEDC)</td>
<td>NIGERIA</td>
<td></td>
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<tr>
<td>Eko Electricity Distribution Company (EKEDC)</td>
<td>NIGERIA</td>
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<tr>
<td>Enugu Electricity Distribution Company (EEDC)</td>
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<td>Ikeja Electricity Distribution Company (IKEDC)</td>
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<td>Jos Electricity Distribution Company (JEDC)</td>
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<tr>
<td>Kaduna Electricity Distribution Company (KAEDCO)</td>
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<td>Kano Electricity Distribution Company (KEDCO)</td>
<td>NIGERIA</td>
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<tr>
<td>Port Harcourt Electricity Distribution Company (PHED)</td>
<td>NIGERIA</td>
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<td>Yola Electricity Distribution Company (YEDC)</td>
<td>NIGERIA</td>
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<tr>
<td>Compagnie Energie Electrique du Togo (CEET)</td>
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<td>Electricity Company of Ghana (ECG)</td>
<td>GHANA</td>
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<tr>
<td>Northern Electricity Distribution Company (NEDCo)</td>
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<tr>
<td>Empressa Publica de Electricidate e Agua de Guine-Bissau (EAGB)</td>
<td>GUINEE BISSAU</td>
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<tr>
<td>Liberia Electricity Corporation (LEC)</td>
<td>LBERIA</td>
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<td>Société Nationale d’Electricité du Burkina Faso (SONABEL)</td>
<td>BURKINA FASO</td>
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<td>Société Béninoise d’Energie Electrique (SBEE)</td>
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<tr>
<td>Société Nigérienne d’Electricité (NIGELEC)</td>
<td>NIGERI</td>
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<tr>
<td>Electricity Distribution and Supply Authority (EDSA)</td>
<td>SIERRA LEONE</td>
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<td>Société Nationale d’Electricité du Sénégal (SENELEC)</td>
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<td>National Water and Electricity Company Ltd (NAWEC)</td>
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<tr>
<td>Electricité du Mali (EDM-SA)</td>
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<tr>
<td>Electricité de Guinée (EDG)</td>
<td>GUINEA</td>
<td></td>
</tr>
</tbody>
</table>

**NB:** The forum is open to any Distribution company within West Africa wishing to join.

### 9. Funding

WAPDUF funding is composed of contributions from distribution utilities, technical and financial partners, distribution equipment suppliers working in the field of improving access to energy.

Leverage Manufacturer and retailer resource through co-operatives (e.g. accelerated depreciation, first year expensing, sale tax holidays) where available.

### 10. Evaluation/Tracking Result

- Conduct process evaluation to ensure that program are working efficiently.
- Conduct impact Evaluation to ensure that mid and long term goals are being met.
- Communicate to key Stakeholders Evaluation result.
Annex 5
## Project Introduction:

This project is designed to identify the total losses of a DISCo relative to energy injected into the distribution network. The project should consider the separation of the losses into Technical and non-technical losses by mentioning the portion of the distribution network used to estimate the technical losses and the actual period of computation.

Summary description of the loss reduction projects and its objectives, project component and project cost, estimated project benefits and ways to improve controls.

<table>
<thead>
<tr>
<th>Nature of Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disco should separate the losses into Technical and non-technical losses. Provide monetary value of high distribution losses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alignment with Corporate Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicate how the project objectives align with corporate objectives in the Corporate Strategic Plan. Otherwise, indicate any regulatory requirements or needs to justify the implementation of the project.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimates of Project Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the benefits to the Discos when the project is implemented Eg. Improving Control</td>
</tr>
</tbody>
</table>
Effects of Non-Implementation:
What does DISCO stand to lose if the project is not Implemented
Eg. Discos will become bankrupt.

Perceived Risks:
Outline perceived project risks and suggest mitigation measures.

<table>
<thead>
<tr>
<th>Description</th>
<th>Likelihood</th>
<th>Impact</th>
<th>Response Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eg. Inability to fund project by DISCo</td>
<td>Low</td>
<td>Very High</td>
<td>Disco can seek alternative financing arrangement from Donors</td>
</tr>
<tr>
<td>Eg. Delays due to procurement challenges</td>
<td>low</td>
<td>Very high</td>
<td>Discos must team up with relevant procurement authorities to ensure due diligence is done for the smooth running of the projects</td>
</tr>
</tbody>
</table>

Time Schedule:
Disco should provide the expected start and finish dates of the project

Project Component and Project Cost:
Disco should provide the ff:
- The estimated product cost and project management cost (kindly attach details).
- High level (quarterly) cash flow over project life cycle

<table>
<thead>
<tr>
<th>PROJECT COST COMPONENTS (US$)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eg. Installation of Capacitor Bank</td>
<td>USD 5,000,000</td>
</tr>
<tr>
<td>Construction of additional substation</td>
<td>USD 3,500,000</td>
</tr>
</tbody>
</table>
Procurement Strategy:
Discos are to indicate the preferred method of procurement and the level of local content for the project as well as the procurement timelines.

Financial and Economic Analysis
Perform investment Appraisal for the project and all identified alternatives employing the appropriate analytical tools as the case may demand e.g. NPV, IRR, EIRR and The Cost Benefit analysis. Other Analysis to be performed may include technical, environmental and risk analysis.

Human Resource Requirements and Internal Capabilities
Determine high level Human resource requirements and capabilities within the Discos required for the implementation of the project e.g. Human Resource skill levels.

Eg. The Human resource requirements and capabilities for the implementation of the project will be obtained from a project implementation unit (PIU) that will consist of a Project Manager, Planning Engineers, Design Engineers, Project Engineers, Project Accountants, Procurement Specialist, field inspectors etc. In the absence of the PIU, the Engineering Services Department of Disco will assist in the project implementation.

Funding Options:
Provide the sources of project funding indicating the preferred option e.g. Donor Funding, grants/loans.

Summary Milestones
Significant events in the project. These can include the completion of key deliverables, the beginning or completion of a project phase or product acceptance.

High Level Payment Schedule:
Projected payments that go with stipulated milestones.

Managing Director of Disco

Name  Sign  Date
Task 3 – Investment plans for the reduction of losses and estimation of associated costs

1.1 INVESTMENT PLAN MODEL

1.1.1 Foreword

In reality, investment projects, which aim at reducing losses in distribution networks will be part of the company’s activities and integrated into its financial statements. For financing institutions, it is the financial performance of the distribution company, which is of prime importance in deciding on a financing request from the company. The expected financial performance of the loss reduction project is of secondary importance. If the financing institutions are convinced that the distribution company will meet the debt service requirements, financing will normally be provided without a close look at the expected financial performance of the project. If, however, the financial situation of the company is weak, financing institutions will be reluctant to finance the loss reduction project even if calculations show that it is very profitable and its revenues largely exceed the expenditures, including those for debt service. Commercial banks will normally ask guarantees for debt service in order to provide financing. Donors may sometimes be less demanding but they often also require guarantees in that case. In the present document, only the financial performance of the loss reduction project is considered. The document describes the elements to be presented in a request for financing and comments on points to be considered in the financial analysis. The comments are illustrated by means of two examples: (i) Installation of Advanced Metering Systems. (ii) Installation of Capacitor Banks.

1.1.2 Elements to present in a proposal for investment projects which aim to reduce losses in distribution networks

1.1.2.1 Presentation of the development of total losses

The project proposal should start with the presentation of the total losses; the total losses in terms of energy and the total losses relative to the energy injected into the distribution network. The total losses are obtained by subtracting the consumption in the considered period from the energy injected in that period into the network.

1.1.2.2 Separating between technical and non-technical losses and presenting the estimated costs of non-technical losses
The project proposal should provide a breakdown of the total losses into technical and non-technical losses. The breakdown should preferably be accompanied by a brief description of the method used to estimate the technical losses and by mentioning which portion of the distribution network has been used to estimate the technical losses and the referred period of calculation.

The monetary value of the non-technical losses should be stated. The value is obtained by multiplying the non-technical losses in terms of energy by the average price paid by the customers (average price net of taxes).

1.1.2.3 Summary description of the loss-reduction project and its objectives

This paragraph contains a summary description of the project and the description of the objectives concerning the loss reduction. The objectives should refer to the situation of the losses the project wants to address and the evolution which was described in the previous paragraph.

1.1.2.4 Description of the project components and the project cost

A detailed description of the project components should be given together with the estimated costs of each component and a time table showing the planned implementation schedule.

1.1.2.5 Estimation of the project benefits

The benefits results from the comparison of the losses with and without the project.

If the project reduces technical losses, that would reduce the energy which has to be produced to satisfy the demand. The benefit is thus linked to the production costs. If the project reduces non-technical losses, that would increase the sales receipts. The benefits are given by the additional receipts.

The identification of the benefits is often not at all simple and always requires careful considerations. The following examples of measures to reduce losses demonstrate that.

**Example 1: Improving controls**

Short-term benefits: Payments received from fraudsters. The payment is normally composed of the amount charged for the estimated stolen energy and a penalty. Data received from several distribution companies indicate that the collected amounts largely exceed the costs of the improved control efforts. Another important benefit of customer controls results from the finding that some customers are not charged the correct tariff. Most often, the tariff should be higher because the connected power exceeds the registered value. That may be due to a registration error made by the distribution company but is usually due to an act of fraud by the customer (replacement of the breaker or fuses). The benefits resulting from the tariff increase are higher sales receipts.

Medium and long-term benefits: It can be expected that more and better controls will reduce fraud. But it is difficult to estimate by which percentage because the development of non-technical losses depends on all
measures which the distribution company implements to reduce losses. While it is theoretically possible to separate between the impact of the individual measures, it is seldom if ever done in reality\(^1\).

**Example 2: Installation of split-type prepayment meters**

Expected benefits: Improved collection efficiency and lower non-technical losses. Detailed statistics are needed to estimate the impact on non-technical losses. The statistics have to show for each customer who received the split-type meter the billed energy before the installation and the billed energy after the installation.

**Example 3: Knowing for each customer to which transformer his premise is connected**

Knowing for each customer to which transformer the customer’s premise is normally done in a two-step process:

1. **First step - Pole enumeration.**
   During pole enumeration, a sign is attached to each pole which indicates to which MV/LV transformer the lines are connected. Pole enumeration requires a sound knowledge of the distribution network and is normally done by technicians from the distribution company.

2. **Second step - Collecting the transformer information during customer visits.**
   The visits are often done in the form of a customer census. The transformer to which the customer’s premise is connected is identified from sign attached to the pole to which the service line is connected. A person doing a customer census must only have a basic knowledge of the distribution network and the customer connections. That knowledge can be obtained by a brief training course. That explains why customer census are often done by people who are recruited for that purpose.

The census is a form of control. The list of registered customers is used when visiting the customers. It is examined in addition whether there are illegal connections. It is thus not surprising that fraudsters are usually detected during the census. If the census is used to also collect customer data, the census may detect customers who are charged the wrong tariff. The census benefits are thus similar to those mentioned in the first example (Improving controls).

Knowing to which transformer each customer is connected can help to reduce losses if two more conditions are in place: (i) meters are installed which record the energy injected into the LV feeders of the MV/LV transformer; (ii) an information system is set up which allows comparing the energy injected into the LV feeders with the energy which the customers have been billed who are connected to the feeder. The comparison would allow to detect areas with abnormally high losses. The areas can then be visited to identify the reasons for the losses and to determine the measures to reduce them. The reasons can be technical losses (overload) or non-technical losses (fraud, errors). As between 50 and 150 customers are typically served by a LV feeder, a relatively small number of customers need to be visited to identify the reasons for abnormally high losses. If meters are only recording the energy on the MV side, the number of customers to be visited would be much higher because MV/LV transformers have several LV feeders.

No distribution company, which participated in this study, has already installed such a system. There is thus no data base which allows estimating the impact of the system on the technical and non-technical losses. That said, being able to compare the energy sent into small areas of the distribution network with the energy billed in that area will certainly help to reduce non-technical losses. Regarding the costs of the system, the

\(^1\) Statistical methods exist which allow to estimate the impact of individual measures. Applying the methods requires long time series or many cross-sectional data and the sound knowledge of the methods in order to correctly interpret the results. It seems that distribution companies face problems to meet these requirements. None of the companies visited by the consultant had applied the methods.
costs of the meters to be installed will be relatively low (≤ 100 Euros/meter). The costs of establishing the information system which integrates the billing data and the energy-sent-out data may be significant but given the large amounts of money lost due to non-technical losses, it is considered very likely that the investment will be highly profitable.

1.1.2.6 Financial analysis and presentation of the results

To obtain financing, the project should meet the following criteria:

- The project’s receipts should allow paying all expenditures (liquidity criterion). The criterion is fulfilled if the cumulated value of the net cashflow is never negative. The net cashflow is the difference between the receipts and the expenditures. If the criterion is not fulfilled, funds have to be injected.
- The project should be profitable for the investor.
- The financial ratios of the project should meet the criteria used by the financing institutions.

The main instruments to be used for the financial analysis are the Cashflow Statement and the Profit & Loss Statement. The project’s Balance Sheet is sometimes also asked by financing institutions. The Cashflow Statement shows the receipts and the expenditures. The Profit & Loss Statement shows the revenues and the costs and important financial ratios can be calculated from the statement. The most important ratio is the debt-service-coverage ratio.

The income tax is calculated in the Profit & Loss Statement. The calculation assumes that the project is a separate entity which has no links with the distribution company. Projects which aim at reducing losses are usually very profitable and would have to pay income tax. In reality, the project will be integrated into the company’s financial statements, however. The company’s income tax rate will usually be lower than the rate used for the project alone because the company has loss-making activities. In fact, its total activities may not produce a profit but a loss.

That the loss-reduction project promises to be highly profitable can often be seen while only examining few periods. If, for example, the financial analyses show that the discounted sum of the receipts exceeds the discounted sum of the expenditures until the end of the debt service period, it will normally not be necessary to consider more periods in the analysis. That would only be needed if there are reasons to believe that the annual expenditures exceed the annual receipts in some of the later years which is likely to be rare.

The discount rate to be used is the so-called WACC, the weighted average cost of capital. The WACC is calculated as:

\[ \text{WACC} = \text{Rd} \times (1 - T) \times g + \text{Re} \times (1 - g) \]

- \( \text{Rd} \) : interest rate of loans plus a risk premium
- \( \text{Re} \) : interest rate of high quality bonds plus a risk premium
- \( T \) : income tax rate
- \( g \) : percentage of the investment costs to be financed by loans

Projects which aim at reducing non-technical losses could often have a short loan repayment period. Data obtained from distribution companies show that projects often produce substantial receipts within short periods. The receipts would allow repaying loans quickly. See the data of distribution companies presented in the main document or the example presented in part B of this addendum (Installation of Smart Metering Systems).
Regarding profitability, calculating typical indicators such as the rate of return on equity or the internal rate of return on the investment\(^2\) is not necessary if it is obvious that the net cashflow will always be positive soon after the investment phase. The return on equity is normally very high if only little equity is injected which is almost certainly the normal case. The challenge of projects which aim at reducing non-technical losses is not the profitability but rather the willingness to implement the project, the financing of the project and its efficient execution.

The presentation of the results of the financial analyses should show that the project’s receipts allow paying all expenditures, including debt service payment, even under conservative assumptions. The presentation of financial ratios should support that result.

It should finally be remembered what has already been said in the Foreword: It is unlikely that commercial banks will contribute to the financing of the project even if the financial analyses of the project show excellent results. Knowing that the project will be part of the activities of the distribution company, the banks will base their decision on the financial performance of the company. If that performance is not considered satisfactory, the banks will normally demand a guarantee unless the requested financing amount is small. The financial analysis of the project alone will be of secondary importance.

1.1.2.7 Comments on economic analyses if asked to be provided by donors

Donors may be willing to provide finances for a loss-reduction project without asking for a guarantee. But donors may ask that the financial analysis be accompanied by an economic analysis which shows that the project is economically attractive for the nation.

A major difference between financial and economic analyses is that the financing of the project and taxes are not considered in economic analyses. Economic feasibility requires that the economic internal rate of return exceeds the economic discount rate or that the sum of the discounted net benefits is positive. The value of 10% is typically used for the economic discount rate.

Another difference is that the costs and benefits are identified from the viewpoint of the country. Estimating the monetary value of economic costs and benefits is difficult because some costs and, in particular, benefits only occur in the long run and have no market value. The comments made below on the economic benefits of loss-reduction measures demonstrate the problems. In practice, the costs entering the financial analysis are usually assumed to also reflect the measurable economic costs (as mentioned, financing costs and fiscal taxes and levies are not taken into account). While that could be a fair approximation of the economic costs of loss-reduction projects, using the benefits calculated in the financial analysis as economic benefits is more critical.

Assume that the reduction of technical losses reduces the production of thermal power plants. As a consequence, the emission of green-house gases will be reduced. That this benefit is difficult to quantify follows from the magnitude of values found on the costs of green-house gas emissions. The reduction of technical losses may also improve the supply quality (less power cuts or voltage fluctuations) or enable advancing electrification. Quantifying these benefits is very difficult\(^3\).

The reduction of non-technical losses produces for the distribution company benefits in the form of additional revenues. The economic benefit depends on the use of the revenues. They can, for example, be

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\(^2\) The return on investment is calculated as the internal rate of return of the annual values: profit after tax plus depreciation minus investment cost.

\(^3\) A study which tried to quantify all benefits of rural electrification was conducted in the Philippines in 1998. The ESMAP Report 255/02 of May 2002 titled “Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits” contains a thorough description of the challenges, the methods used to quantify the benefits and the results.
used to improve the power supply quality or to advance electrification. That it is very difficult to quantify these benefits has already been mentioned. The additional revenues could also be used to reduce the Government’s financial support of the distribution company. The Government would then have more funds for other purposes. Determining what these funds will be used for is difficult and even more so estimating the monetary value of the benefits resulting from the use of the funds. The method typically used is to assume that the benefits equal the additional revenues. That is certainly a very crude approximation but understandable in view of the intrinsic problems of quantifying economic benefits.

1.2 EXAMPLE N° 1 – INSTALLATION OF ADVANCED METERING SYSTEMS

1.2.1 Introduction

The term « advanced metering system » is used here for electronic meters which allow communication with the meter from the distance. Advanced metering systems, also referred to as smart meters, exist for about 20 years. The initial technology, referred to as AMR (Advanced Meter Reading), only allowed one-way communication: the electronic collection of data stored in the meter. For several years, the AMI (Advanced Metering Infrastructure) technology exists which allows two-way communication. The distribution company has access from the distance to the data stored in the meter and can change parameter values of the meter from the distance. The AMI technology may also allow the customer to observe from the distance real-time values recorded by the meter. That may help him to reduce the costs of electricity supply by making changes in his electricity consuming equipment.

Several communication technologies exist. The three most important ones are: (a) wireless technology (Wifi), (b) PLC (Power Line Carrier) and (c) traditional telephone lines. In reality, a mix of the technologies is often used. For example, PLC for the transfer between clusters of meters and a concentration point (substation, transformer, communication tower) and wireless technology for the transfer from the concentration point to the utility data center and vice versa.

The installation of advanced metering systems should start with a prefeasibility study which, taking into account the existing regulation, standards and communication systems, makes recommendations on the system to be installed. A pilot project should then test the recommended system before embarking on large-scale installation. The following project proposal assumes that the results of a pilot project are available.

The proposed investment project aims at reducing non-technical losses through the installation of an advanced metering system which focuses on large customers. The data do not reflect those of a distribution company which participated in this study but are hypothetical data. The data have to be replaced by the data of the distribution company, which plans to install the system, and the text has to be modified in line with the situation of the company.

The text aims at obtaining funds from donors or a guarantee which would be necessary to obtain funds from commercial banks. The text is not the tender document for suppliers of the required equipment.

In Africa, problems linked to data transfer and data security are still sometimes obstacles to the use of advanced metering systems⁴. In view of these problems, the consultant recommends holding a seminar where distribution companies of the ECOWAS region are informed about advanced metering systems. Companies, which have already installed such systems, should inform the audience about: the installed advanced meters, the used communication technologies, the software used to manage the system, the costs of the system, the realized benefits, etc. In the ECOWAS region, distribution companies, which use

advanced metering systems for large customers, comprise CIE (Côte d’Ivoire)\textsuperscript{5}, ECG (Ghana) and CEET (Togo). Pilot projects are ongoing at EDM-SA (Mali) and NAWEC (Gambie).

1.2.2 Development of customers, sales and losses in recent years

Table 1 shows that the total losses varied between 17.5\% and 19.0\% in the last five years with a slight upward trend.

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of customers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textbullet MV customers</td>
<td>1 450</td>
<td>1 500</td>
<td>1 550</td>
<td>1 590</td>
<td>1 650</td>
</tr>
<tr>
<td>\textbullet LV customers</td>
<td>950 000</td>
<td>1 000 000</td>
<td>1 050 000</td>
<td>1 150 000</td>
<td>1 220 000</td>
</tr>
<tr>
<td>Billed sales (GWh*)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textbullet MV customers</td>
<td>700</td>
<td>720</td>
<td>760</td>
<td>810</td>
<td>880</td>
</tr>
<tr>
<td>\textbullet LV customers</td>
<td>1 450</td>
<td>1 550</td>
<td>1 660</td>
<td>1 800</td>
<td>1 950</td>
</tr>
<tr>
<td>Energy injected into the distribution network (GWh)</td>
<td>2 606</td>
<td>2 785</td>
<td>2 962</td>
<td>3 214</td>
<td>3 494</td>
</tr>
<tr>
<td>Total losses (% of energy injected)</td>
<td>17.5%</td>
<td>18.5%</td>
<td>18.3%</td>
<td>18.8%</td>
<td>19.0%</td>
</tr>
</tbody>
</table>

* Includes internal consumption

The technical losses in 2016 are estimated at 40\% of the total losses. About 60\% have consequently been non-technical losses (NT losses). Valued at the average price paid in 2016 of 100 FCFA/kWh, the NT losses in 2016 translate into lost revenues of about 40 billion FCFA (≈ 61 million Euros).

1.2.3 Summary description of the project and its objectives

The project foresees the installation of an advanced metering system, comprising the meters, the communication system and the software for data handling and evaluation.

The project aims at reducing the NT losses of MV customers where the advanced meters would be installed. Based on controls of MV customers, it is estimated that they account for at least 25\% of the NT losses. To reduce the losses, 80\% of the meters of existing MV customers shall be replaced by advanced meters and 80\% of all new MV customers shall be equipped with advanced meters. The reason to limit the installation at 80\% is that 20\% of the MV customers are in areas where the installation of the communication system would be too costly.

The results of a pilot project indicate that the advanced metering system will reduce the NT losses of MV customers. Our conservative estimate is that the NT losses will be reduced on average by 10\%. The

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\textsuperscript{5} CIE has also started using advanced metering for LV customers. But CIE has not done meter reading from the distance for several months because of security problems. Meter reading is presently done by portable terminals.
reduction is probably due to the sending of a signal by the meters if the customer tries to manipulate the meter. Knowing that the distribution company will be informed, fraudulent activities decline. The advanced meters have many other important benefits. They allow supervising the energy supply in real time and changing, if necessary, supply parameters from the distance. These benefits are not taken into account in the present document.

1.2.4 Detailed description of the project

1.2.4.1 Number of advanced meters to be installed

The total number of advanced meters needed to replace 80% of the meters which are installed at existing MV customers by end of 2018 and to equip 80% of new MV customers until the end of 2021 with the meters is estimated at 1560; 1416 for replacement and 144 at new customers. The estimate assumes that 1770 MV customers will exist by end of 2018 and 180 new MV customers will be connected between 2019 and end of 2021.

The cost of the advanced meters, which allow two-way communication, is estimated at 500 Euros per piece. The estimate includes the cost of material needed for the installation and the cost installation cost. The estimate is based on the price paid for the meters, which were installed in the pilot project.

1.2.4.2 Communication technology

Based on the recommendations made in the Prefeasibility Study and the results of the pilot project, the following communication technology is planned to be used:

Description of the planned communication technology. The description should justify the selected technology in terms of needed bandwidth, data security, existing technology that can be shared, interference etc.

1.2.4.3 Centralized Information System

The centralized data handling system consists of computers and software, which collects and analyzes the received data and allows sending commands, which change parameter settings in the customer’s meter. The software must be able to draw conclusions from the received data, which are important for our company. The development of the software, its installation and training in its use are part of the project.

The project includes the supply of hardware (computer). The hardware and the software must enable the safe storage of the received data and protect the system to the extent possible from access by unauthorized persons.

Hardware costs are estimated at 8 000 Euros; the software costs at 50 000 Euros.

The text has to be changed if the hardware or the software have already been installed by the pilot project. Maybe, that only an increase in the storage capacity of software modifications is then necessary.

1.2.4.4 Training

Training is needed in two subjects:
a. Training in the installation and parameter setting of the advanced meter.
b. Training in the software used for the handling and evaluation of the received data and the sending of commands to the meters.

Training costs are estimated at 20 000 Euro for each subject. The training has to be done in our company.

1.2.4.5 Planning

Mid of 2018: Contract signature.
End of 2018: Start of delivery of meters and components of the communication system.
Early 2019: Start of installation of advanced meter. Training in installation and parameter setting.
Mid of 2019: Installation of hardware and software and start of training in the use of the software.
End of 2020: End of replacement of existing meters (1368 meters).
End of 2021: All advanced meters (1560) installed.

1.2.5 Results of economic and financial analyses

1.2.5.1 Economic feasibility

The costs entering the comparison of the situation with and without the project are: the investment cost of the advanced metering system, the annual O&M cost of the system and the cost which would accrue in the absence of the project. The latter are the costs of the traditional meters which would be installed at new MV customers without the project. The analysis calculates with 200 Euros for a traditional MV meter. The total costs of these meters are avoided costs in the cost comparison and thus deducted from the costs of the advanced metering system.

The avoided kWh losses multiplied by the average price paid in 2017 by the MV customers are used to reflect the economic benefits of the project. The average price paid in 2017 was 120 FCFA/kWh (= 0.183 Euros/kWh) which is roughly in line with our estimate of the economic supply cost of MV customers in 2017. The benefit calculation assumes that existing MV customers who will receive an advanced meter in 2019 or 2020 will, on average, receive it by mid of the year. In the year when the meter is installed, the benefit thus equals half of the annual benefit. New MV customers in a given year are assumed to also be connected by mid of the year.

Table 2 shows that the project is very profitable. The benefits exceed the costs from 2019 onward and the cumulated value of the net benefits is positive from 2020 onward. The result is based on conservative assumptions. The installation of the advanced meter is, for example, assumed to only reduce the NT losses by 10%. But even more conservative assumptions do not jeopardize the profitability of the project. If, for example, the specific consumption of the MV customers is 50% lower from 2019 onward, the cumulated value of the net benefits is still positive from 2020 onward. That is also true if the project reduces the NT losses by 5% instead of 10%⁶. If both assumptions materialize, the cumulated value of the net benefits is positive from 2021 onward.

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⁶ Table 2 only shows the results up to and including 2022 because that short period already shows that the project is very attractive as follows from the result that the cumulated value of the net benefits is already positive in 2020. Indicators of economic feasibility such as the economic internal rate of return have to be calculated from data of longer periods. Calculating such indicators is not necessary if the period up to and including 2022 shows already that the project is economically attractive.
1.2.5.2 Financial feasibility

Table 3 shows the Cashflow Statement, which includes the financing flows. The table is based on the assumption that 10% of the investment costs will be financed by equity and 90% by a loan which carries an interest rate of 12% and has to be repaid in two instalments in 2020 and 2021. The repayment thus starts in the year after the currently existing MV meters have been replaced at 80% of the MV customers.

Table 3 shows that debt service does not pose a problem. The receipts due to the project are much higher than the debt service costs and, in fact, much higher than the total recurrent cost\(^7\). The loan could in principle already be fully repaid in 2020.

Sensitivity analyses show that only if the two very conservative assumptions materialize which have been mentioned above (specific consumption 50% lower from 2019 onward and only 5% reduction of NT losses) will it be necessary to inject funds in 2020 and 2021 in order to meet the debt service commitments.

The financial profitability is high, independent of which profitability measure would be used. That follows from the result that the cumulated net cashflow exceeds the investment costs already in 2020 and that both when not discounting the net cashflow values and when discounting them with the WACC\(^8\).

1.2.6 Conclusion

The results show that the project is very profitable. The problem is that our distribution company cannot finance the project from own funds. Our financial situation only allows a contribution of 10%. We, therefore, ask for a loan or a guarantee which would allow us to obtain a loan from a commercial bank.

\(^7\) The annual costs include income tax payments. The assumption that the project pays income tax is very conservative. The project will be integrated into the distributed company. Although the project is highly profitable, it may well be that it will not make the distribution company a profitable company.

\(^8\) The WACC calculation is based on the following values: loan financing 90%, interest rate 12%, risk premium to be added on interest rate 5%, income tax rate 35%, equity financing 10%, interest rate of high quality bonds 6%, risk premium to be added for return on equity 5%.
Table 2: Costs and benefits of the project

<table>
<thead>
<tr>
<th>Costs and Benefits of Installing an Advanced Metering System to be Used for a Large Portion of MV Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of MV customers</strong></td>
</tr>
<tr>
<td>No. of advanced meters ordered for existing MV customers</td>
</tr>
<tr>
<td>No. of advanced meters ordered for new MV customer (2019 - 2021)</td>
</tr>
<tr>
<td>No. of advanced meters installed at existing MV customers</td>
</tr>
<tr>
<td>No. of advanced meters installed at new MV cust. (2019 - 2021)</td>
</tr>
<tr>
<td>No. of advanced meters installed at new MV cust. (2019 - 2021)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of advanced meter</th>
<th>Euros per meter</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of hardware and software for centralized data center</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>29.0</td>
<td>29.0</td>
<td>29.0</td>
<td></td>
</tr>
<tr>
<td>Cost of training</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Total investment cost</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>454.6</td>
<td>454.6</td>
<td>454.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avoided costs (trad. meter for new cust.)</th>
<th>Euros per meter</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual O&amp;M cost</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>-</td>
<td>4.5</td>
<td>9.0</td>
<td>9.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific consumption of MV customers</th>
<th>kWh/yr</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT losses of MV cust. without AM in % of specif. cons.</td>
<td>12%</td>
<td>kWh/yr</td>
<td>581,763</td>
<td>570,128</td>
<td>558,725</td>
<td>547,551</td>
</tr>
<tr>
<td>Billed consumption of MV customer without AM</td>
<td>kWh/yr</td>
<td>69,812</td>
<td>68,415</td>
<td>67,047</td>
<td>65,700</td>
<td>64,392</td>
</tr>
<tr>
<td>NT losses of MV cust. with AM</td>
<td>kWh/yr</td>
<td>511,952</td>
<td>501,713</td>
<td>491,678</td>
<td>481,845</td>
<td>472,208</td>
</tr>
<tr>
<td>Billed consumption of MV customer with AM</td>
<td>kWh/yr</td>
<td>62,830</td>
<td>61,574</td>
<td>60,342</td>
<td>59,135</td>
<td>57,953</td>
</tr>
<tr>
<td>Energy benefit derived from MV customer with AM</td>
<td>kWh/yr</td>
<td>518,933</td>
<td>508,554</td>
<td>498,383</td>
<td>488,415</td>
<td>478,647</td>
</tr>
<tr>
<td>Monetary benefit from MV cust. with AM</td>
<td>Tariff (Euros/kWh)</td>
<td>6,981</td>
<td>6,842</td>
<td>6,705</td>
<td>6,571</td>
<td>6,479</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monetary benefit derived from all MV customers with AM</th>
<th>Euros per meter</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project cost</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>450.2</td>
<td>444.7</td>
<td>9.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Net benefit</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>(440.2)</td>
<td>24.1</td>
<td>1,174.1</td>
<td>1,834.82</td>
</tr>
<tr>
<td>Cumulated net benefit</td>
<td>Euros per meter</td>
<td>1000 Euros</td>
<td>(440.2)</td>
<td>(410.1)</td>
<td>938.0</td>
<td>2,792.8</td>
</tr>
<tr>
<td>Financing:</td>
<td>Equity</td>
<td>10% Loan</td>
<td>90% Loan</td>
<td>Loan conditions</td>
<td>Start repayment</td>
<td>End repayment</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>-----------</td>
<td>----------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>For WACC calculation: Interest rate high quality bonds</td>
<td>6% Risk premium equity and lo</td>
<td>5% WACC</td>
<td>11.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Cashflow Statement

<table>
<thead>
<tr>
<th>Expenditures</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment expenditures</td>
<td>1000 Euros 454.6</td>
<td>454.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual O&amp;M cost</td>
<td>1000 Euros</td>
<td>-</td>
<td>4.5</td>
<td>9.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Working Capital</td>
<td>1000 Euros</td>
<td>-</td>
<td>1.1</td>
<td>1.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Repayment of loan</td>
<td>1000 Euros</td>
<td>-</td>
<td>-</td>
<td>386.0</td>
<td>432.3</td>
</tr>
<tr>
<td>Interest payments</td>
<td>1000 Euros</td>
<td>-</td>
<td>49.1</td>
<td>98.2</td>
<td>51.9</td>
</tr>
<tr>
<td>Income tax</td>
<td>1000 Euros</td>
<td>-</td>
<td>137.0</td>
<td>490.3</td>
<td>608.1</td>
</tr>
<tr>
<td>Total expenditures</td>
<td>1000 Euros 454.6</td>
<td>509.3</td>
<td>631.3</td>
<td>923.9</td>
<td>617.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receipts</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receipts due to reduction of NT losses</td>
<td>1000 Euros</td>
<td>-</td>
<td>468.8</td>
<td>1,383.1</td>
<td>1,844.2</td>
</tr>
</tbody>
</table>

| Equity for financing investment expenditures | 1000 Euros 45.5 | 45.5 | - | - | - |
| Loan disbursement | 1000 Euros 409.1 | 409.1 | - | - | - |
| Net Cashflow (preliminary) | 1000 Euros - | 414.1 | 751.8 | 920.3 | 1,222.9 |
| Equity to avoid cash deficits | 1000 Euros - | - | - | - | - |
| Net Cashflow (not discounted) | 1000 Euros - | 414.1 | 751.8 | 920.3 | 1,222.9 |
| Cumulated value | 1000 Euros - | 414.1 | 1,165.9 | 2,086.2 | 3,309.1 |
| Net Cashflow (discounted with WACC) | 11.0% 1000 Euros - | 335.8 | 549.1 | 605.3 | 724.3 |
| Cumulated value | 1000 Euros - | 335.8 | 884.8 | 1,490.1 | 2,214.4 |

### Income Statement

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td>1000 Euros</td>
<td>-</td>
<td>468.8</td>
<td>1,383.1</td>
<td>1,844.2</td>
</tr>
<tr>
<td>Annual cost</td>
<td>1000 Euros</td>
<td>-</td>
<td>5.0</td>
<td>10.2</td>
<td>8.4</td>
</tr>
<tr>
<td>Depreciation</td>
<td>Lifetime (years) 20</td>
<td>1000 Euros</td>
<td>22.7</td>
<td>45.5</td>
<td>45.5</td>
</tr>
<tr>
<td>Interest</td>
<td>1000 Euros</td>
<td>-</td>
<td>49.1</td>
<td>98.2</td>
<td>51.9</td>
</tr>
<tr>
<td>Profit (Loss)</td>
<td>1000 Euros</td>
<td>-</td>
<td>391.3</td>
<td>1,229.3</td>
<td>1,737.4</td>
</tr>
<tr>
<td>Cumulated value</td>
<td>1000 Euros</td>
<td>-</td>
<td>391.3</td>
<td>1,620.6</td>
<td>3,358.0</td>
</tr>
<tr>
<td>Income tax</td>
<td>35% 1000 Euros</td>
<td>-</td>
<td>187.0</td>
<td>480.3</td>
<td>608.1</td>
</tr>
</tbody>
</table>