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Planning tools and methodologies for rural electrification

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Thematic group

Tools and technologies for rural electrification

AUTHORS

Samuel WATCHUENG

Adrien JACOB

Romain FRANDJI

THEMATIC COORDINATION

Ivory Coast Electricity Operators (SOPIE)
Business Unit (BU)

01 BP 8529 Abidjan 01 Côte d'Ivoire

Tel. : +225 20 20 60 39

Fax: +225 20 32 74 77

Site Web : www.sopie.ci

Email : jlyao@sopie.ci

CONTACTS:

Jean-Luc YAO BI, Business Unit Director

Yves-Serge AHOUSSOU, Head of the Research Dept.

CLUB-ER SECRETARIAT

Innovation Energies Développement (IED)
2 Chemin de la Chauderaie

69340 Francheville, France

Tel. : +33 4 72 59 13 20

Fax : + 33 4 72 59 13 39

Site Web : www.club-er.org

Email : secretariat@club-er.org

CONTACTS:

Denis RAMBAUD-MEASSON, Managing Director

Anjali SHANKER, Deputy Managing Director

Samuel WATCHUENG, Strategy and development Director

This document was written based on experiences of CLUB-ER members and exchanges during thematic workshops organized by CLUB-ER, with the help of the CLUB-ER Secretariat and of experts. It is intended as a work paper to feed think tanks and to share experiences between African institutions in charge of rural electrification.

LIST OF ABBREVIATIONS

CAP REDEO	Capacity and institutional strengthening for Rural Electrification and development, Decentralised Energy Options
ECOWAS	Communauté Économique des États de l'Afrique de l'Ouest
CEMAC	Central Africa Economic and Monetary Community
DME	Department of Minerals and Energy
PSRP	Poverty Reduction Strategy Paper
ENABLE	A wearable system supporting services to «enable» elderly people to live well, independently and at ease
ENERGIS	Planificácion Energética Regional utilizando tecnologia GIS
DRE	Decentralized Rural Electrification
ESMAP	Energy Sector Management Assistance Program
GEOSIM	Geographic Simulation for rural electrification
HOMER	Energy Modeling Software for Hybrid Renewable Energy Systems
IDH	Indice du Développement Humain
IMPROVES-RE	Improving Economic and Social impact of Rural Electrification
JASP	Jiaotong Automatic System Planning Package
LAP	Low Voltage Electrification Analysis and Planning
LAPER	Logiciel d'Aide à la Planification d'Électrification Rurale
LEAP	Long-range Energy Alternatives Planning
LIRE	Lao Institute for Renewable Energy
MEPRED	Mainstreaming Energy for Poverty Reduction and Economic Development
NEPLAN	Power System Analysis and Engineering
MDG	Millennium Development Goals
PANERP	National Energy Plan for Poverty Reduction
PDSE	Electricity Sector Development Plan
PERG	Global Rural Electrification Programme
PDSEN	Energy Sector Development Programme
SME	Small and Medium Enterprises
POWERWORLD simulator	The Visual Approach to Analyzing Power Systems
PV	Photovoltaïque
RETScreen	Clean Energy Project Analysis Tools
SIG	Système d'Information Géographique
SOLARGIS	Integration of renewable energies for electricity production in rural areas
SWER	Single Wire Earth Return
UEMOA	Union Economique et Monétaire Ouest Africaine
ViPOR	The Village Power Optimization model of electric Renewables
WASP	Wien Automatic System Planning Package
ZEM	Multi-sector Electrification Areas

MEMBERS OF THE STUDY GROUP PARTICIPATING IN THE WORK

ABERME	Agence Béninoise d'Electrification Rurale et de Maîtrise de l'Energie (Beninese rural electrification and energy conservation)
ACER	Agence Centrafricaine d'Electrification Rurale (Central African Agency for Rural Electrification)
ADER	Agence de Développement de l'Electrification Rurale (Rural electrification development agency) (Madagascar**)**
ADER	Agence de Développement de l'Electrification Rurale (Rural electrification development agency) (Mauritania**)**
AER	Agence d'Electrification Rurale (Rural electrification agency (Cameroon)
AMADER	Agence Malienne pour le Développement de l'Energie Domestique et l'Electrification Rurale (Malian agency for domestic energy and rural electrification development)
ANER	Agence Nationale d'Electrification Rurale (National agency for rural electrification) (Congo)
ARSEL	Agence de Régulation du Secteur Electrique (Regulation agency for the electric sector) (Cameroon)
ASER	Agence Sénégalaise d'Electrification Rurale (Senegalese rural electrification agency) (Senegal)
BERD	Bureau de l'Electrification Rurale Décentralisée (Bureau of decentralized rural electrification) (Guinea)
CER	Cellule d'Electrification Rurale (Rural electrification agency) (Niger)
DE	Direction de l'Energie Energy Division (Chad)
DER	Rural Electrification Division (Ivory Coast)
DGE	Direction Générale de l'Energie (Energy general management) (Central African Republic)
DGE	Direction Générale de l'Energie (Energy general management) (Togo)
DGERH	Direction Générale de l'Energie et des Ressources Hydrauliques (Energy and water resources general management) (Gabon)
DNE	Direction Nationale de l'Energie (Energy general management) (Guinea)
FDE	Fonds de Développement de l'Electrification (Electrification fund) (Burkina Faso)
FDSEL	Electricity Sector Development Fund (Congo)
SOPIE	Ivory Coast Electricity Operation Company
ONE	Office National de l'Electricité (National electricity agency) (Morocco)

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Executive Summary

The Club of African Agencies and Structures in charge of Rural Electrification (CLUB-ER) is a network of over thirty public institutions responsible for rural electrification in Africa. By pooling expertise and experience feedback, CLUB-ER aims to strengthen the capacities of African rural electrification institutions and to provide adequate solutions to this issue.

This document is a summary of the discussions and analyses on the tools and methodologies for the planning of rural electrification carried out within the "Tools and technologies for rural electrification" study group, coordinated by Ivory Coast Electricity Operators (SOPIE) over the period 2008-2010.

www.club-er.org

1 Key issues on the planning of rural electrification

In order to clarify the issues and thus better understand the specific characteristics of the various approaches and existing tools, it is important to first identify the key challenges in planning rural electrification. This is not intended to be an exhaustive exercise. However, it is an attempt to systematically analyse the main themes central to rural electrification planning approaches, using the seven-question method (Who does What, Where, When, How, How Much and Why):

- **Who plans rural electrification** (who are the key actors in the planning)? It is an accepted fact that the development of a sub-sectoral policy on rural electrification is a matter for the State, and responsibility for this returns often legally to the Administration in charge of Electricity. However, prior to the reforms which led to the reorganisation of the electricity sector, including in some cases the privatisation of national electricity companies, the planning stage was sometimes managed by these companies, and then vertically integrated. The reforms, and in some cases the privatisation of these companies, are accompanied by renewed interest in rural electrification planning actually managed by the State. In some instances, this is motivated by newly instituted agencies and structures in charge of rural electrification. It is important to mention, however, that greater precision in the regulatory texts would be beneficial in terms of the nuances between the different phases of (i) sectoral strategy, (ii) planning and (iii) investment programming, and thus in terms of the unequivocal sharing of responsibilities between the entities entrusted with these duties. Decentralisation policies are increasingly allowing local communities greater choice in terms of planning, in the same way that the tendency towards multi-sector collaboration is progressively leading to decompartmentalisation in electrification planning, which is henceforth shared between other key rural development sectors.
- **What do we plan** (what are the planning objectives)? On the basis of the access to electricity's objectives defined by the rural electrification strategy, planning consists in establishing a coherent outline for optimising an objective function. This is usually a somewhat sophisticated economic criterion for investment choices (Discounted kWh cost, Cost-Benefit ratio, Internal Rate of Return, Net Discounted Value) within a set of constraints that can at the same time be political, technical, financial, strategic, etc. With the trend impulsed by the Millennium Development Goals (MDGs), we adapt from now on this approach also by taking into account the contribution of the electrification to the access to the energy services in rural zone.
- **Where do we plan** (the territory being covered)? Regardless of the definition adopted nationally, in countries where a national electricity company coexists with structures in charge of rural electrification, rural areas in the sense of electrification, refer to all of the territories not yet electrified, including urban embryos or already urbanised settlements: This is most commonly the case in CLUB-ER member countries.
- **When do we plan** (at what time and within what time frame)? Planning occurs at the beginning of the rural electrification process, once the strategy and thus the objectives and institutional responsibilities are set. It is integral to the notion of time (medium and long-term) and precedes the investment programming (short term). The time horizon for rural electrification planning should not be too distant (for example, between 10 and 20 years), so that uncertainties regarding the parameters/hypotheses can be limited. In each case, a maximum five-year planning period is suggested, with regular revision of the plan.

  The choice of horizon can have an impact on investment decisions: a short horizon could present a favourable case for a less costly investment option, owing to a more rapid return on investment. A far-off horizon could justify the implementation of stop-gap measures, often referred to as “pre-electrification”, in communities for which planning is done at a later stage.

➤ **How do we plan** (what are the planning approaches used)? It is suggested distinguishing mainly two approaches for the planning of rural electrification within a given time horizon, given the objectives (generally bound to the access to energy in a given territory) and constraints which could be political technical, financial and strategic at the same time: the so-called technico-economic approach, which aims only to optimise an economic criterion (objective function) by allowing investment choices based on maximised distribution of the energy produced by various comparative technologies, and the so-called multi-sector approach, which entails an economic optimisation identical to the previous one, with however the introduction of a qualitative dimension to the energy distributed (the same kWh distributed have a different impact on human development).

These different approaches require the elaboration of fairly sophisticated models allowing to simplify complex electricity systems, and facilitating the simulation of various scenarios; information technology tools (expert systems or decision-making tools) allow then the easy realization of digital simulations, based on powerful calculations.

➤ **How much does this cost** (what is the cost of planning)? Unfortunately, rural electrification planning could prove prohibitively costly if the necessary recurring revisions and the options for easily performing various simulations are not properly planned. These costs basically include fees for gathering socioeconomic, technical and economic data, as well as the cost of expertise, whether internal or external, associated with the processing and analysis of this data. The processes used for sharing multi-sector data allow to decrease very significantly the costs associated with data collection and the update of the data.

The update of planning results – which are furthermore very sensitive to changes in parameters and calculation hypotheses – and of investment programming, requires frequent renegotiation and an internal appropriation of planning processes.

Managing a rural electrification planning tool can be a sustainable alternative to the repeated and costly use of external expertise. However, the tool must be adaptable to the vision and sovereign objectives of rural electrification planning, and present a good value for money over the long term.

➤ **Why do we plan** (what is the justification for planning)? The aim of rural electrification planning is to fulfil the general objectives defined by the sectoral strategy, for example, maximisation of access to electricity within a given territory and within a given time horizon, for a specified level of subsidisation: a sovereign approach in which it is increasingly important to integrate a dimension of spatial planning and strengthening of the economic and social impact of rural electrification.

This exercise helps to validate the feasibility of the objectives set, and paves the way for the more operational phase of investment programming. This is an instrument for transparency and visibility within the sector, particularly for private operators.

Planning results can also be used to argue in favour of corrective measures for accelerating the development of rural electrification, given the existing regulatory framework (a policy favouring renewable energies, technical standards, taxation, tariff policy, conditions for third-party access to the network, etc.).

2 Planning methodologies and tools: state of the art

A state of the art of planning tools and methods is carried out. This is a typological analysis of the methodologies currently being used in the field of rural electrification planning, as well as an inventory of available tools, all from the perspective of the key issues raised in the first section:

- ➤ In the interest of simplification, it is proposed that the methodologies referred to as **“demand-based”** be distinguished from those referred to as **“supply-based”**. Specifications and examples of application are given for each of the approaches;
- ➤ Three categories of tools are identified: tools for (i) sizing production options, (ii) sizing networks, and (iii) territorial planning. While the first two categories of tools are more commonly implemented and are used more for conception and feasibility studies, there are few integrated planning tools, undoubtedly due to the unsystematic character of the methodologies used, and to the limited demand for rural electrification plans easy to be updated.

3 Experiences and practices within CLUB-ER: state of affairs

The state of affairs of current practices within CLUB-ER was established from the results of a survey conducted in 2008 within the members of the thematic group: “Tools and technologies for rural electrification”. This concerns the discrepancies observed between the state of the art and practices observed within the CLUB-ER, and discussed within a workshop for sharing experiences and practices, held in Abidjan on the 26th and 27th of November 2008. This event led to the organisation of a training workshop on rural electrification planning for the benefit of CLUB-ER members, in Grand Bassam (Ivory Coast) from the 27th to the 29th of July 2010.

4 Conclusions and recommendations

The burden of history

It is to be noted that throughout its long maturation, the progress of rural electrification has been strewn with counter-productive, often dichotomous and sometimes dogmatic oppositions: decentralised vs. centralised, networked vs. non-networked, renewable energy vs. fossil energy, rich vs. poor, urban vs. rural, domestic use vs. productive use, upstream vs. downstream, etc.

These conceptual oppositions have very widely influenced the planning models within recent years, and finally have only resulted in slowing down the effective expansion of the access to energy services in rural areas.

Now if it is a reality which henceforth seems to become established, it is that on a given territory and on a given horizon:

1. All of the technological options can be accommodated, whether or not they are connected to the interconnecting network, based on renewable or fossil energy, etc. The fact of having a balanced, optimised supply within a given territory falls within the concept of an “energy mix”. The determining factor in the composition of this mix is primarily the availability of the resource, and the economic conditions for production, transport and distribution of the energy produced as a result, in light of the quality of service desired, the ability of users to pay and possible state subsidies;
2. Domestic, community and productive-sector users are all of equal importance with regard to human development through improvements in social welfare, improved education and healthcare, and access to income in rural communities, respectively, as indicated by the components of the Human Development Index (HDI);
3. Although new concepts relating to energy services lead to greater consideration of end-service provision and the meeting of human requirements, rather than the energy source or production, transport or distribution technologies, it would be inopportune to arbitrarily compare the Upstream (which refers to the system of production, transport and distribution) with the Downstream (the energy end-service). Inasmuch as the upstream can exist

without a relevant downstream, there cannot be a sustainable downstream without the development of an economically viable upstream. Furthermore, the different sources of production cannot be compared in terms of the quality of service provided;

4. Financial transfers between categories of subscribers are intrinsic to the economic balance of electricity systems. This balance is only actually obtained by combining the “richer” customers’ ability to pay with that of the “poorer”[1] customers, large consumer with small consumers, etc. Moreover, these transfers can in theory be made at different levels, including between electricity systems run by various operators, between urban and rural systems, etc., depending on the provisions adopted in accordance with the regulations relating to the national tariff policy: a single tariff structure should not be considered a dogma.

Recommendations for improving rural electrification planning

Consequently, in the interest of optimising the access to electricity for all, CLUB-ER is in favour of adopting planning methodologies and tools for rural electrification which will help to define an optimal energy mix covering a given territory and time horizon, based on three principles which must henceforth be vigorously implemented:

- **Consideration of the ultimate goal which is the economic and social impact of electricity at territorial scale**, and which goes beyond electricity to land-use planning issues;
- **Technological neutrality and real costs policy in optimising electricity supply options,** unless a technological prioritization is specified in the national sectoral policy: for example, in terms of promotion of local resources, development of a technological sector, or even promotion options which can provide a better quality of service;
- **The need for a minimal access to energy services for the development of certain areas within the territory**, including the consideration of relatively higher subsidies.

Furthermore, because of the specificities of the rural electrification explained through systematic questioning which guided the analysis, the sovereignty of States must also be registered as a cross-cutting principle. Indeed, real costs policy argues in favour of a structural imperative of differentiated subsidies in order to achieve a balance between production, operation and maintenance costs, the users’ capacity to pay, and an acceptable level of profitability for private operators. Subsidisation as a compulsory requirement consequently engages the government in a central role.

The State as a planning agency should therefore be able to advisedly “control” the measures taken and the planning tools used. From this perspective, it becomes necessary to strengthen the capacities of the various public structures (agencies and national structures in charge of rural electrification), including the decentralised ones (local authorities) henceforth involved in the rural electrification planning process. This along with the mastering of the planning tools respecting the principles above, and authorizing easy updates.

In order to be more effective, the State must beforehand clarify its responsibilities in relation to (i) the creation of the sectoral strategy, (ii) rural electrification planning, and (iii) investment programming.

[1] Often very far below the energy expenses in conditions of non-electrification as observed from surveys.

Key issues concerning rural electrification planning

1

The following points raised should serve to provide food for thought and discussion on rural electrification planning methods and tools. In an attempt to define the issue in its entirety, it is proposed that an approach based on a systematic seven-question method (Who does, What, Where, When, How, How much and Why) be adopted:

- Who does the planning (who are the key figures)?
- What do we plan (what are the objectives)?
- Where do we plan (the territory being covered)?
- When (at what time and within what time horizon)?
- How do we plan (following what method)?
- How much does it cost?
- Why do we plan (for what reason)?

These various questions are addressed and summarised in this chapter.

1 1 Who does the planning?

1 1 1 Between legality and legitimacy

The planning of rural electrification, included as an aspect of electricity sector policy, is essentially a sovereign exercise, the responsibility for which falls to the State.

By way of example:

- Act n° 98-29 which governs the electricity sector in Senegal consequently states that "...The Minister in charge of Energy shall devise and then propose to the President of the Republic the general policy as well as the norms applicable to the electricity sector."
- In Burkina Faso, act 016-2005 states in article 7 that "the Ministry in charge of Energy is responsible for energy policy, for the strategic planning of electrification, for regulations and for control of electricity infrastructures...".
- In article 40 (paragraph 1), act n° 98-22 governing the electricity sector in Cameroon states that "The administration responsible for electricity shall provide for the design, implementation and monitoring of government policy in the electricity sector, while taking account of technological developments in the sector, the development needs and the priorities defined by the Government in this domain. Paragraph 2 states that "the Administration responsible for electricity shall in addition carry out rural electricity planning".

The task of formulating sectoral strategy/policy for electrification is therefore legally the duty of the State, and in some contexts as in Cameroon, the stage after planning remains in the hands of the Ministry responsible for Energy.

However, historically, in situations where national electricity companies were almost merged with the State, this highly sovereign duty has in actual fact been assured by these vertically integrated public companies. Since these companies were more legitimate and better equipped for such a task, the administration responsible for Electricity has ultimately performed only a supervisory function. This is still the case in contexts where the liberalisation of the energy sector has not been undertaken or where the national electricity company remains a State company.

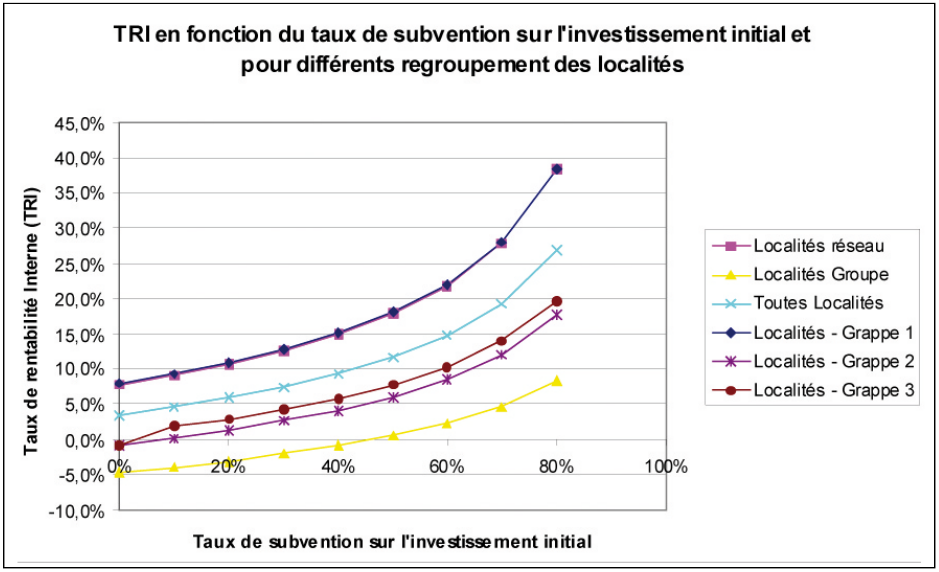
1 1 2 The return in grace of planning carried out by the State

Since the late 1990s in particular, when the implementation of reforms led to the emergence of new structures in the electricity sector (regulators, electrification agencies, electrification funds, etc.), and especially to a more distinct separation between the State and national electricity companies, including privatised ones, we have been assisting to a return in grace of a planning effectively carried out by the State.

This usually involves applying the Government's vision in terms of balanced access to energy services on a national scale, and, as far as possible, the equitable geographic distribution of public resources in a sector where the need for subsidisation is not anymore a taboo.

This situation enhances today the legitimacy of the State as a planning agent.

Graph 1. Subsidisation of rural electrification: case of the Central Province of Cameroon[2]



The graph above provides an example of the growth in the Internal Rate of Return (IRR) for rural electrification projects identified in the Central Province of Cameroon in 2002, for various levels of locality groupings (by clusters or type of technology), various technical solutions and various levels of subsidisation.

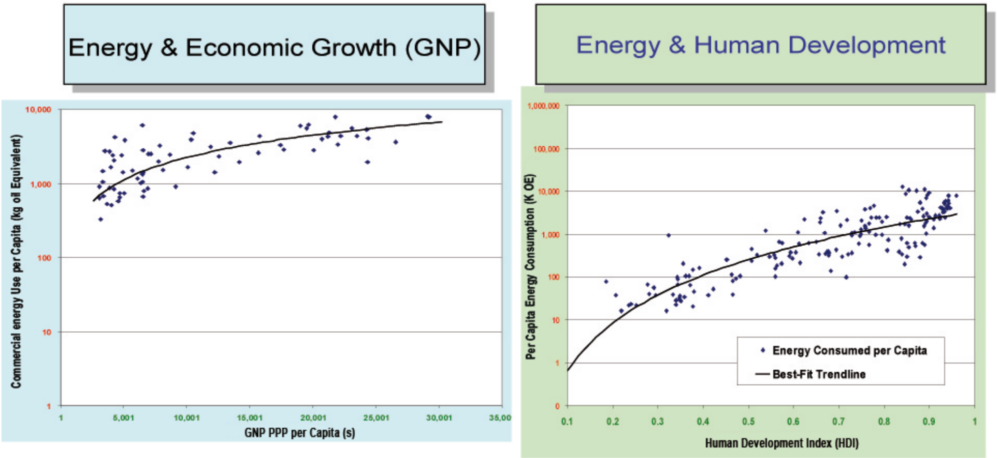
It is quite evident that without subsidisation, decentralised rural electrification projects are generally not viable, particularly once they are outside of the interconnected network.

The State therefore resumes responsibility for the sovereign duty of electrification planning, and particularly for the planning of rural electrification, which is now more than ever decisive for the short, medium and long-term development of energy access within national territory.

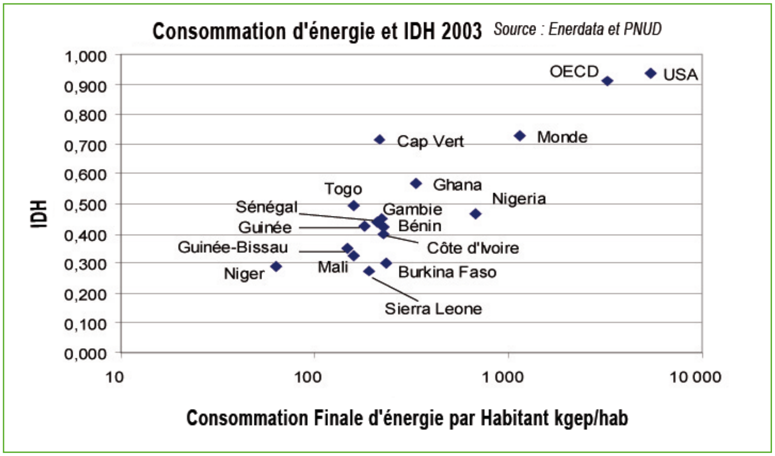
As illustrated in the graphs below, the links between access to energy and development are now sufficiently documented and generally accepted as to justify the extensive involvement of States in the planning phases[3].

[2] Decentralised Rural Electrification in the Central Province, AER/AFD (Renewable Energy Agency/French Development Agency) Study, 2002.
[3] Note from the IMPROVES-RE (Improving Economic and Social impact of rural electrification) project concept, FDI/European Commission (COOPENER), 2005-2007.

Graph 2. Links between energy and development



Source : World Bank



In addition, it should be noted that particularly since 1998, several CLUB-ER member countries have undertaken various planning and investment programming studies on rural electrification, at various levels (national, regional, etc.)[4], and this has generally been done with the assistance of international cooperation.

These planning documents should then form the basis for technical and economical guidelines and investment choices in the rural electrification sub-sector.

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4 This is especially the case in the Ivory Coast (Rural Electrification Master Plan, 1999), Cameroon (Rural Electrification Master Plan, 1999), Niger (Rural Electrification Strategy, 2004), Burkina Faso (National Electrification Plan, 2002), etc.

1 1 3 Imprecise concept-definition, and effects on the sharing of responsibilities among State structures

The three extracts from the regulatory frameworks cited above (2.1.1) also illustrate the lack of precision that can be encountered in several of the texts, where the boundaries between the three phases of (i) sectoral strategy, (ii) planning and (iii) programming, though different, are not always clearly identified. This often leads to conflicts of interest between the public entities which one-sidedly assume the responsibility for these phases:

- Strategy relates to national or territorial policy on the subject, allowing to fix the objectives and to coordinate the actors and the actions to reach these objectives, taking strengths and weaknesses into account, as well as risks and opportunities;
- Planning, indivisible from the concept of time, consists on the other hand in organising over the time (medium and long-term) the realisation of the fixed objectives. Unfortunately, it is rather frequent that various stakeholders (Ministries, agencies, funds, national companies, etc.) do in fact share the responsibilities for planning, but without any coordination among themselves;
- Being more of an operational exercise, investment programming actually consists in choosing priority investments and scheduling these over the short term.

In certain cases such as Burkina Faso, the term 'strategic planning' is used, referring to the formulation by the Ministry responsible for Energy of an especially concrete and precise strategy already including a planning dimension.

1 1 4 Other actors and their connection to the planning

Next to the Administration responsible for Electricity, other actors are involved in the electricity sector (companies under the authority of the state or private operators), which are connected in numerous ways with the planning process:

- Agencies and Structures in charge of Rural Electrification
- Regulators
- Operators
- The special case of the National Electricity Company

A The Agencies and Structures in charge of Rural Electrification

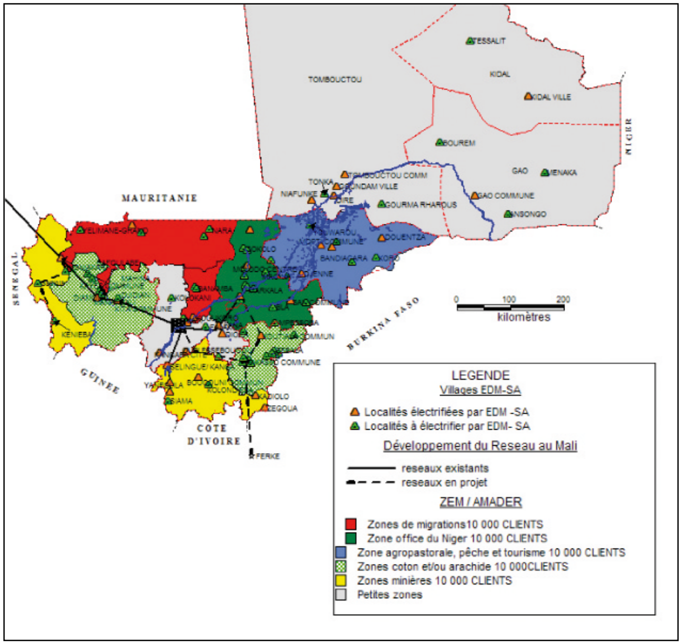
As their task is the promotion and development of rural electrification on a national territorial scale, whenever these agencies and structures exist, planning is often a fundamental aspect of their operations. In fact, it helps define the priorities, technological options and economic conditions for investment. This is especially the case in situations where a systematic approach has been adopted (advanced decision-making on strategic options regionalised on a national scale)[5] as distinct from situations where the project/programme approach (action taken as dictated by financing opportunities, for example) is still given preference[6].

As a result, the achievement of the objectives assigned to these agencies and structures depends significantly on the hypotheses adopted at the time of planning: These hypotheses are based on the demand and its evolution, on technological solutions and related technical constraints, on the costs and ability to pay, etc.

[5] Ivory Coast, Senegal, Mali, Burkina Faso, etc.
[6] Cameroon, Niger, RCA, Congo, Chad, etc.

Moreover, planning, which in some instances is legally the responsibility of the Ministries in charge of Electricity, has often historically been managed by national electricity companies. However, in the revised situations, planning/programming initiatives are in some instances undertaken by the agencies and structures in charge of rural electrification, due to this heavy dependence on planning. This is in spite of the fact that these agencies and structures are ill-equipped for the task (cf. section 4.4). This phenomenon has been observed particularly in Senegal and Mali, and more recently in Cameroon[7].

Graph 3. AMADER map section showing the Multi-sector Electrification Areas in Mali (ZEM)[8]



In the particular case of Electrification Funds, planning results provide guidance in their choices of strategic investment and the allocation of state subsidisation. The main value of planning for the Funds is thus based on the rational use of the available resources for the most effective projects, in theory, depending on criteria established in advance. By identifying projects, planning can also be useful in finding potential investors, by means of preliminary financial and economic analyses demonstrating the feasibility of the projects identified, so that the available public funds can then be used as leverage for obtaining more substantial resources.

B The Regulators

The analysis of the behaviours of the regulator towards the rural electrification planning helps to establish a dual relationship, upstream and downstream of the process:

[7] The initiative for the revival/relaunch of planning, while admittedly managed by the Ministry of Energy and Water Resources, has just been set in motion by the institution of a Rural Energy Fund within the Rural Electrification Agency.

[8] Source: AMADER-Mali

- On the one hand, the regulator imposes conditions upstream on which the courses of action to be taken in relation to planning will depend: conditions for the entry of new operators into the sector, conditions for the access of third-parties to the interconnected network and more generally for the management of international border relations between two operators, applicable norms and standards, the defining of an acceptable IRR for the operators, etc.
- On the other hand, the regulator is provided with planning results in the daily exercise of his duties, insofar as these will determine both the technical and economic conditions for the rational development of electrical power supplies: justification for the issuance of documents of title, the promotion of competition and private sector participation, the framing of the third-party access to the network through the drafting of purchase-type contracts for renewable energy, the defining of a tariff policy, etc.

As a result, this duality reveals an ambiguous and sometimes contradictory relationship between the regulator and the planning of rural electrification, more so when the duty of regulation is performed by an entity other than the structure in charge of promoting rural electrification:[9] an entity that is alternately binding and utilitarian.

C The Operators

These are natural and legal persons having the right to operate a business in the electricity sector. This right is obtained through delegation by the Electricity public service, in accordance with contracts signed with the State. Though they play no part in the planning process, these entities are involved by virtue of the planning results, bearing in mind that these results define within a given horizon, the areas for electrification which will be given priority by the State, the consequent development plans, and the preferential technological options. Planning thus serves as a tool for strategic positioning in the rural electrification marketplace and therefore as a tool for prior identification of business opportunities.

However, it is important to point out that, although not directly involved in the planning process, the profile of potential operators will have a determining impact on the planning approach adopted. In fact, a master plan which in principle leaves the space for local initiatives (local communities, NGOs, SMEs) – and thus for small-scale projects – will not be the same as one primarily targeting companies having a capital base and a greater capacity to perform. In practical terms, we observe a growing tendency towards targeting a combination of public and private entities (Senegal, Mali, Burkina Faso, etc.) for the operation of the systems.

D The special case of the National electricity company

In non-reformed context or situations where the national electricity company has not been privatised, it is often the national electricity company which in actual fact conducts the electrification planning, as previously illustrated in section 2.1.1. Rural electrification planning from its point of view therefore consists of an extension of its internal procedures for developing infrastructures (production, transport, distribution), with or without adaptation to the specific characteristics of the rural community (advanced analysis of the demand, simplified technical specifications, etc.), and an oftentimes centralising tendency in the conception of a global electricity system[10].

[9] AMADER in Mali (the Malian Agency for Household Energy and Rural Electrification) into which the three roles are condensed (promotion of RE, regulation and funds) is from this perspective is an uncommon component of CLUB-ER.

[10] The case of ONE (Office National de l'Electricité (National Electricity Office)) and PERG (the Global Rural Electrification Programme) in Morocco is a rather uncommon one: although network connection at the end of 2006 represented close to 90% of connection methods (27,373 villages), ONE has also adopted decentralised methods: 2,540 villages equipped with photovoltaic kits, 2 with wind-diesel hybrid power systems, 12 with motor generators, and 2 hydro-electric mini-plants programmed to provide electrification for 2 villages.

In situations where a reform has printed a certain type of liberalisation of the electricity sector, and even more so when the electricity company has subsequently been privatised, the latter consequently restricts itself to honouring its contractual obligations which means that an investment programme is periodically negotiated with the State. Nonetheless the company continues to have a determining role in the planning of rural electrification, by facilitating (or not facilitating):

- The precise demarcation of territories not falling under its development plan within the horizon under consideration ("the potential" for decentralised rural electrification) and,
- The expansion of opportunities for interconnection (purchase or sale of energy surplus) on the existing transport/distribution network, should the need arise.

Table 1. AES-SONEL contractual commitments related to growth of the service[11]

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
	PII	PIII	PIV	Après contrat	Après contrat
ADAMOUA	14893	20682	24943	15586	15586
NORD	20523	25733	32923	20548	20548
EXTRÊME-NORD	21054	28170	32061	20999	20999
GRAND NORD	56470	74585	89927	57133	57133

The table above shows the contractual commitments of AES-Sonel, the takeover entrepreneur of the Sonel national electricity company, privatised in Cameroon in July 2001 and holder of a concession contract up to 2021. The commitments are expressed in new service connections per 5-year period, from 2006 to 2026. However, it has not been specified whether this is due to increased density in communities already supplied with electricity or to connections to be made as additions to the electricity service.

1 1 5 Planning in a decentralisation context

As the decentralisation policies in force are somewhat advanced in CLUB-ER member countries, local authorities (communes, regions, etc.) are acquiring general competence in local development planning and are involved in the design of land-use planning plans.

Generally speaking, constructing a facility on the territory of a local authority cannot be undertaken by the State or by another local authority without the prior consultation of the authority concerned.

Consequently, local authorities are increasingly being given responsibility or at least being included in the planning process. In certain situations, they are clearly receiving competence in electrification (public lighting and sometimes rural electrification).

However, the question is often raised with regard to the relevant scale for local planning of rural electrification, given the specificity of the electric systems, optimized according to a logic of «networks» with the potential for transport over long distances, and characterized by a strong dependence between the secondary arteries and the structuring lines.

An optimal local electrification plan should therefore normally be constructed in relation to the overall system and its prospects for development. In this way, the definition of a relevant scale would encourage the overstepping of administrative boundaries: territorial decompartmentalisation favouring the bridging of communities, regions and borders, etc., with the major constraint in rural areas often being the availability of a local source of energy at a reduced cost.

[11] Cameroon Electricity Sector Development Plan (PDSE), Ministry of Water and Energy Resources (2006).

1 1 6 The trend towards a multi-sector approach and joint action by multiple stakeholders

Since the 2002 Johannesburg Summit, and the identification of Millennium Development Goals, the multi-sector approach is gradually becoming a guiding principle in policies targeting the access to energy services in rural and suburban areas.

In its White Paper (2005), ECOWAS (the Economic Community of West African States) states that "...energy programmes must, in the future more than they have in the past, be based on the identification of needs and services for the territorial development, and on the coordination with other sectoral investments in order to guarantee a substantial economic and social impact, as well as a market..."[12].

This principle has also been used by CEMAC (Economic and Monetary Community of Central Africa) in its Action Plan (2006) for access to energy services in rural and peri-urban areas[13].

As a result, even though the cross-cutting nature of energy justifies it, we are witnessing an unexpected structural trend in the electricity sector towards greater coordination between public actors (education, healthcare, agriculture, etc.), with the objective of strengthening the impact of rural electrification on rural development (cf. multi-sector approach in section 2.5.1B).

Thus, through the influence of the ECOWAS White Paper, Ministries in charge of Energy in ECOWAS countries have set up several multi-sector Groups since 2005.

More recently, as part of the Energy Sector Development Programme (PDSEN) which has since June 2008 been a beneficiary of World Bank credit, Cameroon has decided to establish by ministerial decree an Enlarged Committee for Rural Electrification Planning and Programming (COPPER), headed by the Ministry of Energy and Water Resources[14].

Who does the planning?

The development of a sub-sectoral policy on rural electrification is a matter for the State, and responsibility for this often legally falls under the remit of the administrative body in charge of Electricity. However, prior to the reforms which led to the reorganisation of the electricity sector, including in some cases the privatisation of national electricity companies, the planning stage was sometimes managed by these companies, and then vertically integrated. The reforms, and in some cases the privatisation of these companies, are accompanied by renewed interest in rural electrification planning actually managed by the State. In some instances, this is motivated by newly instituted agencies and structures in charge of rural electrification. It is important to mention, however, that greater precision in the regulatory texts would be beneficial in terms of the nuances between the different phases of (i) sectoral strategy, (ii) planning and (iii) investment programming, and thus in terms of the unequivocal sharing of responsibilities between the entities entrusted with these duties.

Decentralisation policies are increasingly allowing local authorities greater choice in terms of planning, in the same way that the tendency towards multi-sector collaboration is progressively leading to decompartmentalisation in electrification planning, which was previously shared between other key rural development sectors.

[12] White Paper for access to energy in rural and suburban areas, ECOWAS/ WAEMU, 2005
[13] Action Plan for access to energy in rural and suburban areas, CEMAC, 2006
[14] On 24 June 2008, the World Bank granted US $65 million in credit for the expansion of access to modern energy in target rural localities and the improvement in energy resource planning and management by all institutions in the sector. The Rural Energy Fund (FER) which is to be set up will be allocated a sum of US $40 million.

1 2 What is planned?

1 2 1 The objective function

A The objectives to be achieved

Planning rural electrification means optimising the access to electricity over a given rural territory, within a given time horizon. It involves proposing a plan for the development of electricity service for the territory under consideration, allowing eventually (planning time horizon) to achieve the objective set by a rural electrification strategy formulated in advance.

Traditionally, this objective can be translated by an electrification rate to be achieved within a time horizon considered with or without the constraints of an investment budget. The concept of an electrification rate can in certain contexts incorporate various nuances. In such cases, one speaks more specifically (based on a terminology not yet approved and which sometimes differs between countries) of:

- Coverage rate (number of electricity-supplied localities /total number of localities: the level of coverage indicates the traditional level of electrification;
- Access rate (number of households in electricity-supplied localities / total number of households: the level of access thus indicates the proportion of households potentially having access to electricity;
- Penetration rate (number of households effectively connected / total number of households): the level of penetration consequently indicates the proportion of households effectively having access to electricity.

In some contexts, priority may be given to the electrification of the capitals of administrative units and/or localities exceeding a given population threshold (criteria known as administrative-demo)[15].

More recently, as previously indicated (section 2.1.6), ideas about the economic and social impact of rural electrification have been infused into the traditional objectives, making the process of planning optimisation more complicated, particularly with the introduction of a concept of the degree of access to energy services.

This concept of energy services, still referred to as useful energy, is used to describe the end-uses which the energy supply allows to fulfil. These services represent the final link in the "energy chain". This concept considers the provision of the end-service and the satisfaction of human requirements rather than the energy source or the production, transport and distribution technologies used[16].

Consequently, based on this new multi-sector approach to rural electrification, kilowatt hours are no longer equally valued, as this depends on their end usage (cf. section 2.5.1B on the multi-sector approach).

Similarly, not all technologies are valued in terms of the quality of service rendered (service reliability, number of hours per day, cost per user, possibility of productive uses, etc.). This is why rural electrification strategies sometimes specify different electrification rate's objectives for differing technologies: networks, mini-networks, pre-electrification systems, etc.

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[15] Improving the potential economic and social impact of rural electrification in Central and West Africa: spatial dimension and dynamics of territories in rural electrification planning, S. Watchueng (Dir.), 2008

[16] White Paper for energy access in rural and suburban areas, ECOWAS/WAEMU, 2005.

B The actual objective function

In every case, in order to achieve the objective set and at a reduced cost, an attempt is often made to optimise an economic criterion, the objective function, which allows the selection of the best economic options for supplying one or several localities and subsequently categorising the projects identified as a result. The value of the objective function thus depends on several cost parameters, both technical and economic: costs for use of the resource, energy transport and distribution, economic discount rate, users' ability to pay, conditions for extension/renewal or simply the evolution of the electricity service over the time, etc.

The most commonly used economic criteria which are therefore used as objective functions in rural electrification planning models are the following: the discounted cost of the kWh, the Cost-Benefit ratio, the Internal Rate of Return (IRR), the Net Present Value (NPV), etc.

1 2 2 The constraints

In attempting to achieve the above-mentioned objective, the optimisation of the objective function (the economic criterion to be minimised/maximised) is carried out under numerous constraints, which can at the same time be political technical, financial, strategic, etc.:

- **Political constraints:** within the context of its town and country planning policy, the State or the Authorities may wish to develop a priority area, or strive for balanced development of the national territory by voluntarily opting for a reduction in spatial disparities in economic and social terms;
- **Technical constraints:** availability of a resource, particularly a renewable one (the offer), near to points of load (the demand), technological conditions for operating the resource, and for transporting and distributing the energy produced. The country's applicable norms and standards can from this point of view be an obstacle to or an accelerator of the development of the access to electricity;
- **Financial constraints:** under conditions of limited availability of financial resources and confronted with a structurally unprofitable activity like rural electrification, each investment made is undertaken from the point of view of the public authorities, to a certain extent, to the detriment of other potential projects in the near future. Hence the need for a geographically equitable and socially acceptable distribution of public resources. In some instances, restrictive constraints such as a maximum investment budget over a given period, a maximum investment budget per locality or per subscriber, etc.[17] may be introduced.
- **Other strategic constraints:** these involve grasping opportunities for accelerated achievement of the objectives set. For example, in view of optimising costs or improving the economic and social impact of rural electrification, some current projects in the electricity sector or in other sectors of rural development can have an influence on planning (cf. multi-sector planning, 2.1.6 and 2.5.1B)[18].

[17] In the case of the MEPRED project in Burkina Faso (2007-2008), a maximum investment limit of 200,000 CFA francs per subscriber has been decided upon: the number of subscribers is that achieved five years after electrification.

[18] Coordinated planning of electrification with the implementation of regional integrated rural development programmes, without an explicit energy component: this is the case with the IMPROVES-RE (2005-2007), and the PDF-Cameroon (2007-2008) projects. Another reference, ESMAP (2008).

What is planned?

On the basis of the objectives for electricity access defined by the rural electrification strategy, planning consists in establishing a coherent outline for optimising an objective function, often a somewhat sophisticated economic criterion for investment choices (discounted cost of the kWh, Cost-Benefit ratio, Internal Rate of Return, Net Present Value (NPV), etc.), within a set of constraints which can be all at once political, technical, financial, strategic, etc.

With the trend encouraged by the Millennium Development Goals (MDGs), this approach is now being tempered and is now taking into account the contribution of the electrification to the access to energy services in rural areas.

1 3 Where do we plan?

1 3 1 The rural environment: a vague definition

Even though the concept has a tendency to evolve: the country or the “rural environment” has historically been the designation used for all cultivated spaces, as opposed to urbanised spaces (towns, built-up areas, industrial zones...).

With regard to electrification, the notion of rural zones can nonetheless have various meanings. In some cases, it can simply be a territory identified by an administrative status (such as rural district, village, township, etc.), while in other cases the emphasis will be placed on a demographic threshold below which a locality is considered as rural. Anyway, in each country, the structures in charge of statistics and general census of populations often propose a national definition of the rural environment, which is intended to be unambiguous.

1 3 2 Cross-cutting specific features, from the viewpoint of electrification

Although this definition of a rural area is necessarily vague, it is still possible, generally speaking, to identify the following specific features:

- **An heterogeneous spatial configuration**, reflecting areas of relatively high population concentration, urban embryos engaging in economic activity (markets, etc.) or administrative activities (public services, decentralised communities), as compared with the essentially agricultural hinterlands;
- **Low population density,** between villages as well as inside the villages themselves;
- **Difficulties of access to localities,** due to an inadequate transport infrastructure which can pose logistical problems for the implementation of substantially-sized projects, and possibly as well natural obstacles (forests, protected areas, mountains, lakes, water courses, etc.) which complicate the transmission routes of electricity lines;
- **A population with limited solvency on average** (low and inconsistent revenue), but whose energy bill is often substantially high, in proportion to revenues earned;
- Relatively low energy requirements, except in cases of specific demand, relating in particular to production (agro-industries, sawmills, irrigation, mills, hulling machines, oil presses, etc.) or community operations (drinking water pumping, etc.).

Where do we plan?

Whatever the nationally adopted definition, in countries where a national electricity company coexists with structures in charge of rural electrification, the rural areas as understood in terms of electrification refer to all of the territories to which electricity has not yet been delivered, even when these are urban embryos or already urbanised developments: this is the most common situation in CLUB-ER member countries.

1 4 When do we plan?

1 4 1 When is it necessary to plan?

In the critical path of the rural electrification process which leads to tangible investments, there are three successive phases mentioned above in section 2.1.3 : (i) strategy, (ii) planning and (iii) programming.

The planning (both medium and long-term) occurs immediately after the sectoral strategy (general and permanent) has been formulated and precedes the investment programming (short-term). In other words, it does not make sense to begin operations in an area without having carried out a planning exercise in advance, as there is a risk that the resources are not optimised.

1 4 2 Within what time horizon?

As the infrastructures for the production, transport and distribution of electricity have a somewhat lengthy lifespan (from 5 years for some power generators to 30 years – especially for distribution networks), planning studies have time horizons ranging from a few years to a few decades (20 years, or even 30 years).

Generally speaking, the more distant the time horizon, the greater the uncertainty over planning parameters/hypotheses and they can potentially transform the planning exercise into a great deal of speculation. These uncertainties affect in particular:

- ➤ Demand and demand growth for the territory and the period studied, more so when this demand incorporates multi-sector hypotheses and land-use management;
- ➤ Electrification options and constraints to their development (cost, availability, fuel costs);
- ➤ Available investment budgets (local, national, international);
- ➤ Etc.

The time horizon may also depend on other horizons set by national or international policy (for example, 2015 for the Millennium Development Goals)[19].

- ➤ **The choice of horizon does have an impact on investment decisions: a short horizon could favour a less costly investment option, by reason of a more rapid return on investment. A far-off horizon could justify the implementation of stop-gap measures, often referred to as “pre-electrification”, in communities for which planning is belatedly carried out.**

[19] Plans such as those formulated as part of the MEPRED-Burkina Faso project (2008, op. cit.), or PANERP (National Energy Plan for Poverty Reduction in Cameroon, 2006) are locked into the 2015 horizon, by way of transition for the first or as a terminal phase for the second. In the case of Burkina Faso, rural electrification planning was set at the terminal horizon date of 2025, as in the case of other sectoral planning designs and the PRSP (Poverty Reduction Strategy Paper).

1 4 3 Revision frequency

In every case, it is essential for the electrification plan to be frequently updated, i.e. before the time horizon considered. It is thought, for example, that the concrete action to be taken following a 20-year plan cannot extend beyond 5 years without revision of the planning.

It is also recommended to extract from the planning results a maximum of five-year investment programming schedule, to be regularly updated taking into account changes in the electricity landscape and the main parameters/hypotheses, particularly relating to costs: fuel costs, rate of depreciation, available budget....

When do we plan?

Planning occurs at the beginning of the rural electrification process, so long as the strategy and thus the objectives and institutional responsibilities are set. It is integral to the notion of time (medium and long-term) and precedes investment programming (short term).

The time horizon for the planning of rural electrification should not be too distant (for example, between 10 and 20 years), so that uncertainties regarding the parameters/hypotheses can be limited. In every case, a maximum five-year planning period of five years is suggested, with regular revision of the plan.

The choice of horizon does have an impact on investment decisions: a short horizon could present a case in favour of a less costly investment option, by reason of a more rapid return on investment. A far-off horizon could justify the implementation of stop-gap measures, often referred to as “pre-electrification”, in communities for which planning is belatedly carried out.

1 5 How do we plan?

1 5 1 Planning approaches

There are presently two major categories of planning approaches:

- The technical-economic approach
- The multi-sector approach

A Technical-economic approach

The goal is to optimise an economic criterion (minimising the discounted cost of the kWh, maximising the IRR, etc.), by distributing the maximum number of kWh produced over the given period, in order to achieve economies of scale. In this way, the most economical supply option can be identified for each locality or group of localities. Moreover, the projects can be classified among themselves.

This is the traditional and most widely used approach, even though it is often moderated by non-technical-economic considerations (cf. section 4.3). As previously mentioned (cf. section 2.2.1), various fairly detailed economic criteria can be used as an objective function: Discounted kWh cost, Cost-Benefit Analysis, Internal Rate of Return (IRR), Net Present Value (NPV)...

Political, technical, financial and other constraints are often set in order to control the optimisation: maximum investment per subscriber or per locality, maximum installed capacity for a project, etc.

This approach tends to favour the dense areas of the population which are located near to the network, or to other sources of energy, including renewable. It consists in maximising the quantities of kWh sold for a given investment, in order to achieve an economy of scale, irrespective of their place of destination (the notion of economic and social impact is disregarded), so long as any demand for energy arises within the territory under consideration.

This approach can thus be considered as being more "energy supply-based".

B Multi-sector approach

The technical-economic optimisation process is identical to the one described above. However, in contrast to the preceding approach, not all the kWh distributed are equally valued, since the intention is to maximise the impact of electrification on social and economic development. Hence, a particular attention is given to the concept of energy services and thus to the uses of electricity (cf. 2.2.1). Additionally, while with a conventional technical-economic approach only the quantities of kWh distributed justify economies of scale and thus minimisation of the objective function, it can be said that the multi-sector approach introduces a qualitative dimension to kWh distributed.

The multi-sector approach arises in part out of the international awareness linked to the Millennium Development Goals (MDGs) and out of the historically limited impact of electrification on rural development, including when it was about Decentralised Rural Electrification (ERD)[20]. These new directions now make it necessary for rural electrification projects to take greater account of this impact on social and economic development and even to be able to justify it, possibly, in a quantifiable manner.

The issue of rural electrification is therefore refocused on the issue of (basic) "energy services" and production usage (revenue-generating activities[21]).

Table 2. Examples of energy services for the healthcare, education and drinking water supply sectors (ENABLE, 2007)

Sector	Energy services	For
Health	Lighting	Night deliveries and visits
Health	Refrigeration	Storage of medicines and vaccines
Health	Heating	Sterilisation of equipment, cooking
Health	Radio communication	Consultations and logistics management
Education	Lighting	Evening classes, pre-exam studying
Education	Information technology	Training in new technologies
Education	Audiovisual	Training material
Education	Photocopying	Training material
Water	Pumping	Irrigation and drinking water
Water	Sterilisation	Purification of drinking water

[20] Citing in particular the report «Impact of solar photovoltaic systems on rural development: FAO study for rural electrification in the 21st century", B.V. Campen, D. Guidi, G. Best, Environment and Natural Resources Service (SDRN), November 1999, www.fao.org

[21] Cf. (ESMAP, 2008)

The goal, therefore, is not to indiscriminately "distribute" kWh, but to target the most beneficial uses based on this new perspective, which requires cooperation between the various rural development sectors from the planning stage.

This economic and social impact can be assessed in various ways:

- **Weighted multi-criteria evaluation:** each aspect of the impact of electrification (improved access to drinking water, education, value creation, etc.) is assessed and incorporated with a certain degree of weighting in order to obtain a single "score". This evaluation can be carried out on each project identified, per administrative entity (cf. the example of Thailand at the provincial level) or for the entire planning procedure.
- **kWh Weighting:** one variant of weighted multi-criteria evaluation is the calculation of distributed kWh with multiplying coefficients according to the services supplied and/or according to the quality of the electricity supply (partial or continuous service). One kWh sold to a domestic user may thus be worth 1 while one kWh sold to a school may be worth 25. This is one way of adapting the logic of electricity to the multi-sector approach.
- **Restrictive multi-criteria evaluation:** the various possible criteria may be considered restrictive; a project is then rejected if it exceeds certain thresholds (e.g. no school electrified, minus X irrigated ha, etc.). The various criteria thus represent "filters" which leave only the projects meeting all of the requirements.

Whatever the method chosen, dialogue and cooperation between the actors in the rural environment (particularly the ministerial departments) are essential for succeeding in combining the many items of data required and for achieving a consensus on the choice and weighting of criteria.

The process can then be extended after planning with a procedure for impact follow-up and assessment.

This approach tends to favour the dense areas of service which are not necessarily dense areas of the population and not necessarily located near to the networks (even if these various factors often correlate).

It is therefore a rather proactive approach, and more "demand-based".

1 5 2 Modelling and simulation

The planning of the rural electrification on a territory supposes the elaboration of models allowing at the same time to represent the current electric system and to predict its evolution for a given horizon. The main issues affecting this modelling are presented hereafter:

a) Demand forecasting;

b) Technical and economic optimisation of the electricity supply options;

c) Spatial dimension;

d) Optimisation limits and the use of simulation.

A Demand forecasting

There are two categories of models for characterising electricity demand and anticipating its evolution:

The **"top-down"** models, inspired by the approaches used for planning in the conventional electricity sector, and based on sophisticated econometric methods and associated trends in demand. Demand forecasting models using linear regression statistical techniques and based on hypotheses of changes in the number of households and tertiary sector GDP, are worth mentioning;

The **"bottom-up"** models, which are based on socio-economic surveys of the area and which use demand profiles from various types of end-users to produce a more detailed reconstruction of demand at the local level.

Although data collection is more costly in the second case, it is often recommended that this method be followed so that the analysis remains relevant to the specific features of rural zones, especially in relation to questions concerning detailed load analysis which are often very low, as well as ability to pay, and market segmentation.

B Technical and economic optimisation of electricity supply options

Three groups of technologies are possible, depending on the context:

1. Network expansion;
2. (Inter) village mini-grids;
3. Independent systems.

For each locality, technical-economic optimisation consists in comparing these options from the perspective of the objective function (minimisation of the discounted kWh cost, maximisation of the internal rate of return, etc.) taking into account the various political, technical, financial and other constraints previously mentioned in section 2.2.2.

Without going into the mathematical details of optimisation algorithms which can sometimes prove very complex, it is important to emphasise that these depend on assorted simplifying hypotheses[22].

Some models can voluntarily introduce a bias into the optimisation process, by making it possible to prioritise conceivable supply options. This is particularly the case when the planner wishes to give the advantage to an option which uses renewable energy.

Instead of promoting certain supply options, other planning approaches favour deliberate exclusion of certain technologies, while others deliberately make them fiercely competitive so as to objectively highlight the most economically relevant solutions.

1. Network expansion

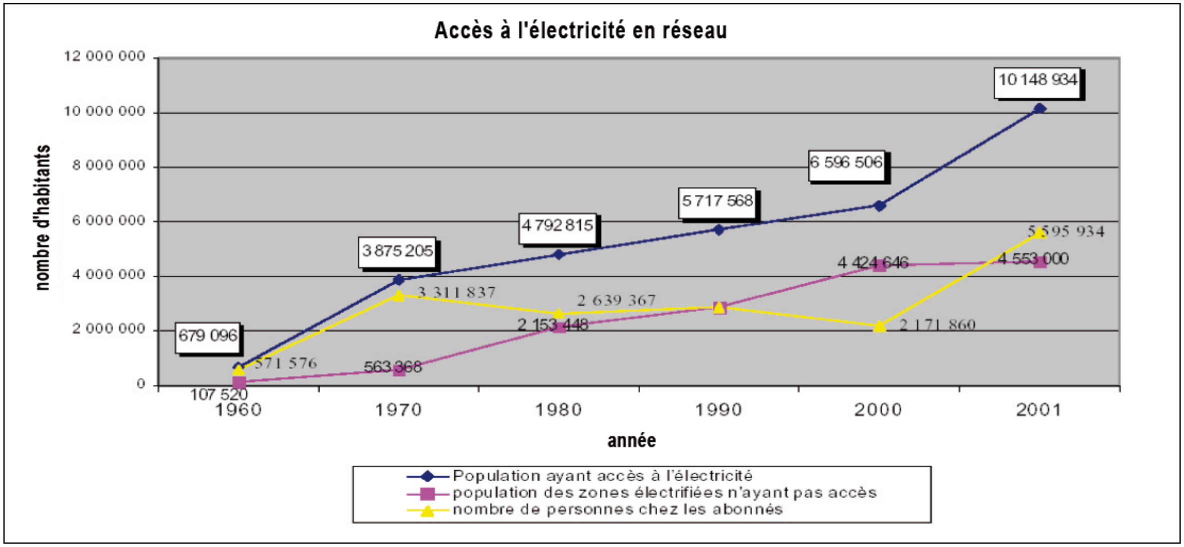
While rural electrification has traditionally been carried out through expansion of the national power grid (with reduced specifications, where necessary), the concept of off-grid electrification has become established as an alternative, particularly within the last decade, due to the difficulty in considering hook-up to the interconnected network as the only option possible, and in light of the degree of failure in satisfying rural demand for electricity. Graph 4 below gives an illustration of this situation in the Ivory Coast, over the period 1960-2001.

The relevance of a solution for connecting to the grid actually depends directly on the distance from the grid and therefore generally on the coverage of the existing electricity infrastructure.

The planning methods based on algorithms are particularly useful here for geographically and rationally demarcating the areas where expansion of the grid is not economically possible within the horizon considered, and require successful collaboration with the national electricity company or with the concessionaire, where the former has been privatised (cf. 2.1.4D).

[22] In order to address power system stability, voltage drops, MV line transmission routes (cf. 2.5.2C), the designing and placement of sub-stations (there are few systematic methods at present which can be translated into algorithms), MV/LV cabling and the designing of transformers (use of ratios such as the number of clients per km of line, the number of transformers per total demand for power for the locality...), the potential for use of renewable energy (summarised mapping study for mini-hydropower, estimate of power units and production), etc.

Graph 4. Degree of failure to satisfy demand in rural areas with access to the grid in the Ivory Coast (1960-2001)



Source : Atelier ESMAP sur l'énergie rurale en Côte d'Ivoire, 30-31 janvier 2002

In any case, technical, economic and regulatory aspects are to be considered in order to determine if connecting to the grid is a relevant option for supplying electricity in rural areas:

- **Technical considerations:** the unavailability of energy on the grid and voltage drops (remoteness from the areas studied in comparison to the sub-stations) sometimes make the solution of connection to the grid non-viable.
- **Economic considerations:** the possibility or not of using simplified technical norms and standards (SWER, wooden poles, adaptations to sections of cables, collective metering systems, low amperage meters, etc.) for expanding the grid in rural areas can promote the growth of rural electrification through connection, by considerably reducing investment costs, or can heavily constrain it.
- **Regulatory considerations:** if the electricity company operating the existing electric grid has the monopoly for the distribution of electricity, it must provide assurance of its willingness to invest in rural electrification (particularly in low-cost grid-expansion), and of its interest in undertaking social projects which are structurally uneconomic or unprofitable. Otherwise, it is necessary to study scrupulously the contractual framework of purchase and resale by private operators on the grid, as well as the possible assistance to investors in this sector.

2. (Inter-) village mini-grids

These are electricity grids built from a system supplying one or more localities (systems referred as clusters), independently of a source(s) feeding the national interconnected grid, with or without a connection to the grid for an injection of surpluses or an occasional purchase of energy, in the particular case of renewable energy (hydroelectricity, biomass, etc.).

With the increase and the high degree of uncertainty linked to the fossil fuel prices, renewable solutions are becoming increasingly competitive.

Notwithstanding, they are generally more onerous than fossil fuel solutions (power generators) in terms of investment in the initial installation, and can therefore be disadvantaged in short-term economic analyses which do not take the externalities into consideration[23].

On the other hand, their variations in daily and seasonal production can pose problems when operating on their own. A long-term perspective and broader local development objectives are nonetheless likely to value renewable energy for its use of local natural and human resources, as well as its reduced impact on the environment. Lastly, hybrid solutions enable the advantages to be combined and the disadvantages of using various energy sources to be reduced (adaptability and availability of diesel systems and the reduced cost of operating a small hydroelectric plant or a wind turbine).

3. Independent systems

In contrast to expansion of the grid and the (inter-) village mini-grids, small independent systems supply a consumer or a limited group of consumers in a given locality. These are:

- PV panels with battery for community (schools, health centres) or domestic use;
- Diesel or solar-cell battery-recharging systems;
- Multifunctional platforms;
- Pico hydroelectric turbines;
- Etc.

Following an attempt at the widespread distribution of individual systems as an alternative to networked systems, particularly in the decade after the Decentralised Rural Electrification concept reached its zenith, this type of option is now considered to be more realistic, targeted, modest in ambition. This is in light of the different limitations observed, in terms of actual access to service as well as economic and financial project viability and reduced impact on local economic development.

Actually, the implementation of this type of system operates increasingly not as a systematic alternative, but a more localised one, in the absence of networked energy, and often contributes to balancing the objectives of service/energy access on the scale of the territory studied, by targeting the remotest areas for Basic Energy Services.

C Spatial dimension of planning models: the issue of collecting and processing geographical data

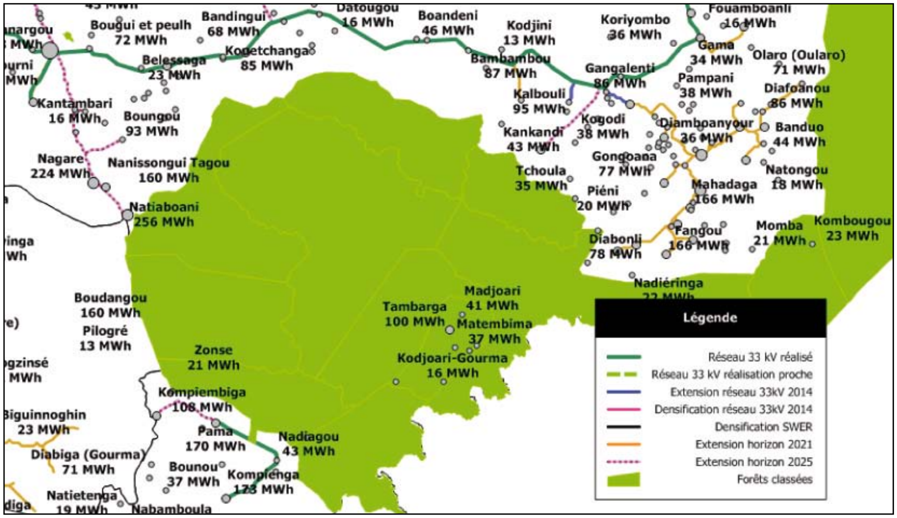
The spatial dimension of electrification planning can be looked at from three angles:

- **Technical-economic:** very basically speaking, supply (national interconnected network, renewable resources – hydroelectricity, biomass, wind or solar potential, etc.), as well as demand (localities, dense areas of population, specific demand, particularly agro-industrial, etc.) are by nature localised in a given territory, and the linkage between supply and demand is first and foremost a geographic equation. The positioning of resources, the distances to the grid or between localities, the dispersal of housing within a locality, etc., are all determining geographic parameters for technical and economic optimisation.

[23] Social and environmental externalities (quality of service, cost of unfulfilled demand – Outage costs-, impact on development and the environment...) taken into account in the form of costs or benefits, which nonetheless presupposes a clear, widely accepted methodology.

- **Geophysical:** the transmission route of MV lines may or may not make allowances for natural constraints (forests, protected areas, lakes, mountains, etc.) and topological expediency (roads, railways, etc.), in order to end up with more realistic solutions. In fact, rather than simplifying it with a bird's eye estimate (including averaging a corrective coefficient if necessary), the transmission route of MV lines between villages or between the national grid and the villages can be optimised automatically[24] or semi-automatically[25]. Graph 5 gives an illustration of the circumvention of a Protected Area by electricity lines in Burkina Faso, thanks to models making use of the graph theory[26].
- **Socio-economic:** with land-use management in mind, there may be an interest in economic exchanges and population movement between localities (hinterland-hub dynamic), in order to primarily target centres of development, for example. A wide variety of models can be used to this aim[27]. Population density among and between villages is also an indicator which can be explored with a view to identifying ad hoc solutions. Graph 6 presents an illustration of the catchment areas for development hubs in Burkina Faso.

Graph 5. Circumvention of a Protected Area by electricity lines in Burkina Faso[28]



[24] Vector or rasterized algorithms (cf. GEOSIM® method).

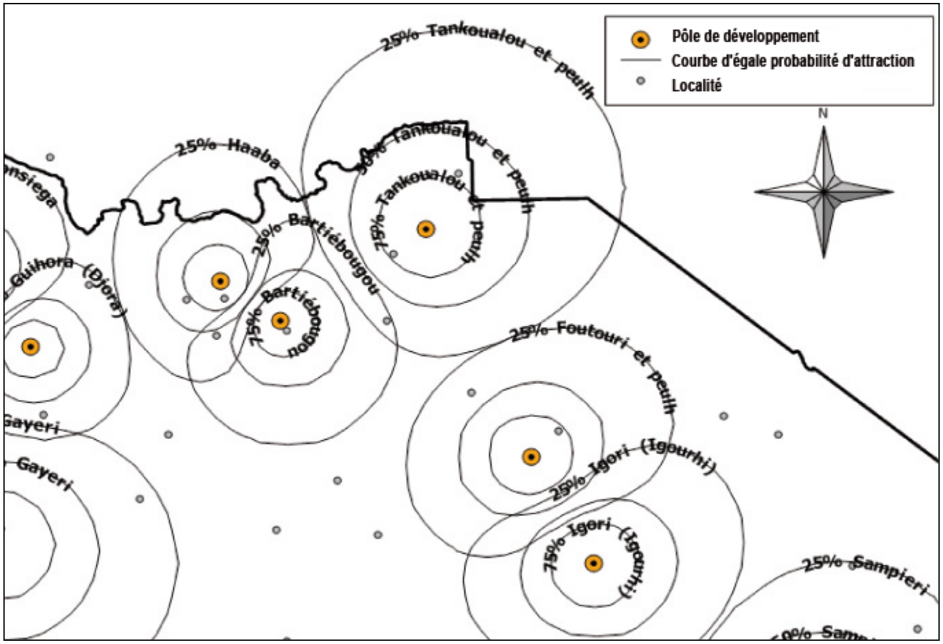
[25]Cf. method used in South Africa (Luchmaya, 2001).

[26] For example, the Least Cost Path Models (LCP)

[27] In particular the methods known as spatial interaction models such as Hotelling's Law, Reilly's Law, proximal sectors methods and Christaller's Central Place Theory, the Huff Model, the Model of Competitive Interaction (MCI), Voronoï polygons, etc.

[28] MEPRED study, 2007-2008, op. cit.

Graph 6. Analysis of the catchment areas in development hubs in Burkina Faso[29]



Thus, in several respects, the spatial dimension is an essential issue in modern planning approaches to rural electrification, and the sensibility of the results to these geographic parameters is beyond doubt.

Processing this spatial dimension is however increasingly made easier by the development of Geographical Information Systems (GIS, cf. section 2.5.3).

However, the matter of the initial availability of referenced geo-data (in the form of maps or digital data) can prove critical, especially in terms of financial impact (cf. section 2.6). It is therefore important to make maximum use of existing sources, by cooperating in particular with other organisations which are likely to hold this information (national geographic institutes, Hydraulics Departments, etc.), particularly within the context of a multi-sector approach, with a view to minimising the cost of area surveys.

D Limitations to technical and economic optimisation the use of simulation

Whatever the optimised variable (objective function), it is useless to aim for the perfect plan, even with the most sophisticated operations research tools (like simulated annealing and genetic algorithms) due to the complexity of the systems studied, the simplifying hypotheses which are necessarily effected in the models and the many uncertainties relative to the quality of the data, among other things.

[29] MEPRED study, 2007-2008, op. cit.

It is also worth noting that whenever the quantity and quality of socio-economic data cannot adequately feed the optimisation algorithms, a minimalist datum can be the population, since this item of data is easier to collect and is transversally present in the various approaches.

In all cases, it is generally recommended that sensitivity analysis be conducted thanks to simulation, in order to measure the extent to which uncertainties on key parameters of the model can influence the result. Whenever the uncertainty is structural (for example, in the case of intermittent renewable energy production), some models even propose treating it probabilistically in the calculations.

1 5 3 From method to computer tool

When the various points mentioned above have been clarified, the relevance of using a dedicated planning tool has then to be assessed, and its characteristics specified in order to bring it into line with the method chosen.

A Need for a computer tool

A computer tool is first and foremost crucial for rapidly performing a large number of calculations. In particular, the disaggregated ("bottom-up") models having a spatial component and incorporating advanced optimisation methods are likely to have algorithms requiring computational capability, such that a non-computer operation is not feasible.

The execution speed provided by a tool furthermore allows various scenarios to be tested (a simulation referred to as digital) and enables sensitivity analysis to be conducted on the results using various key parameters from the model.

With the development of Geographical Information Systems (GIS) offering possibilities for digital programming, it is increasingly easy to integrate a spatial dimension into the technical-economic analysis models and thus to manage the geophysical and socioeconomic issues previously mentioned in section 2.5.2C directly within the planning algorithms.

Moreover, recommendations have been put forward for the regular revision of the electrification plan so as to take account of changing contexts and the progress of the projects, which justifies the capitalisation of the competence for planning through automatized and interactive tools.

B Expert system or decision-making tools?

Due to the complexity of the planning exercise, the issue of the tool's flexibility must be considered and in particular the possibility or not for the planner to intervene at different stages. There are therefore two approaches:

- **The expert system:** the tool is almost a replacement of the planner and functions as an intelligent "black box" into which are entered data and parameters. It outputs conclusive results (unless, of course, calculations with different parameters are entered again).
- **The decision-making tools:** at various stages in the planning, the tool uses automatic or semi-automatic algorithms (with manual input by the user at one or more locations in the loop) which supply a range of results from which the planner has to make a choice based on key indicators.

The advantage of the second approach is, naturally, its flexibility and transparency and the option it gives the planner to intervene at almost any point in the planning process. However, the tool can become tedious or over-complicated to operate if the user enters an excessive computational load.

The expert system, for its part, is often quicker in giving final results, but if the model is not clearly understood by the user, it can prove very difficult to enter parameters, and its results may not be easy to interpret. On the other hand, the expert system is unable to meet the specific requirements of the user, for, as seen in the preceding points, there is a wide variety of approaches and it may be difficult (and hardly desirable) to anticipate them all when designing the tool.

C Independent tools or a coherent whole?

As planning has traditionally been the result of a process broken down into sub-activities (demand forecasting, supply options, demand-side management strategies, transmission and distribution…), various tools are used for various tasks, and these tools do not necessarily communicate with each other. It is therefore the planner's responsibility to ensure consistency and interaction among these various modules.

Recent applications generally include a Geographical Information System (GIS) for spatial modelling and data management, as well as the plotting of results in the form of a map. And depending on the accuracy of the study, it is also possible to use independent software for the optimisation, gauging and economic analysis of electricity systems (renewable energies, hybrid systems, distribution networks). However, these varieties of software are generally not designed to work together with each other, and their approach does not necessarily fit the planning options chosen.

This is why a suite of integrating software programmes can be advantageous, although theoretically it may be less flexible in performing each task. In particular, if the human means provided for the planning are reduced, it is more cost-effective to train a limited team of persons to use one integrated tool than a large number of specialised tools.

How do we plan?

It is proposed that two main planning approaches be identified for rural electrification within a given time horizon, in view of the objectives (usually associated with access to energy in a given territory) and constraints which could be political as well as technical, financial and strategic: the so-called technical-economic approach, the aim of which is solely to optimise an economic criterion (objective function) enabling investment choices to be made by maximising the distribution of the energy produced by various comparable technologies, and the so-called multi-sector approach, which brings about economic optimisation identical to the one just mentioned, but with the introduction of a qualitative dimension to the energy distributed (kWh distributed are not equally valued, in terms of human development. These various approaches call for the creation of fairly sophisticated models which are able to simplify complex electricity systems, and to facilitate the simulation of various scenarios; information technology tools (expert systems or decision-making tools) which make digital simulations easy to perform, based on reliable calculations.

1 6 How much does it cost?

There is a considerable cost attached to rural electrification planning, which moreover is on-going, insofar as it involves a dynamic process to be repeated over time, as already mentioned. However, the initial costs which can be substantial, must be distinguished from the recurrent costs, which, if they are properly supervised, can prove more reasonable.

1 6 1 Initial costs

These can be divided into two components:

- The costs associated with field surveys

- The costs of the planning process itself.

Each of these costs is outlined below.

A The cost of fields surveys

This is the cost associated with the initial setting up of a planning scheme and rural electrification investment programming. These costs include, as the main item of expenditure, the collection and processing of data.

It involves altogether:

- **Socio-economic data:** forecast studies of the various types of demand for electricity within the territory studied and an analysis of paying capabilities, an analysis of the dynamics of the territory with a view towards land-use management within the horizon studied, an estimate of the demographic parameters (population and annual growth rate, household size, etc.), etc.
- **Technical data:** analytical inventorying of potential energy sources, including renewable sources (hydroelectricity, biomass, etc.), electricity-supplied localities, technical characteristics of current and projected electrical infrastructures (lines, substations, etc.), and a technical analysis of the available supply options;
- **Economic data:** mainly the estimate of the characteristic parameters and costs of the main items falling under investment in the production, transport and distribution of electric power, discount rates charged and agreed to, etc.

The collection of these various data requires surveys conducted by expert profiles covering various disciplines (socio-economists, energy engineers, economists, GIS experts, etc.), who are also responsible for processing and analysing the data (design of planning models, creating of simulations, analysis of results and investment programming).

The surveys will be somewhat onerous, depending on the size of the territory, the conditions of access (state of the roads, means of communication, etc.) in the study area, the number and size of the localities, the progress of analytical inventory of potential sources of electric power, the availability of data on the cost of investment and operations and expansion/upgrading (material, equipment, operation and maintenance, etc.), availability of mapping data, etc.

With the introduction of Geographical Information Systems (GIS) for simplified management of the spatial component, which is in several respects a determining factor in planning exercises, this data must in addition be geo-referenced, and this adds to the difficulty and generates additional costs.

The costs for data collection can be lowered significantly in cases where there is an actual process for the exchange of multi-sector data. This is notably the case in Rwanda where there is an organisation in charge of collecting GIS data from all the ministries (CGIS-NUR, http://www.cgisnur.org/)[30], and which has been initiated in Cameroon as part of the GTMN (www.mng-cameroon.org/sig)[31].

B Processing costs

These are the costs necessary for defining and implementing a planning method supplied with the collected and processed data mentioned above. They are therefore essentially expertise costs.

[30] The "Geographic Information Systems and Remote Sensing Regional Outreach Center" (CGIS) was established in 1999 as part of a convention between the "National University of Rwanda (NUR)" and the "Dian Fossey Gorilla Fund International (DFGFI)".

[31] Groupe de Travail Multisectoriel National (National Multi-Sector Task Force), set up in 2005 and headed by the Board of the Ministry of Electricity and Water Resources.

Inasmuch as the investment planning/ programming exercise is a sovereign exercise and needs to be constantly repeated, it is advisable that this process be managed internally.

It may also be necessary to use the services of a consultant engineer as a technical assistant to initiate the process, on condition of compulsory in-house skills training and knowledge transfer. In this case, the costs for technical assistance can be determined by the market, and may result from consultation on an Invitation to Tender, for example.

Besides expertise costs, whether internal or external, the planning process may require the acquisition of software programmes (for office automation systems and calculations) and computing equipment (computers, printers, GPSs, graphic digitizers, etc.) in order to facilitate the processing, data analysis and results output aspects.

1 6 2 Revision costs

As indicated earlier, it is essential to regularly repeat the investment planning/ programming exercise, in order to take account of uncertainties which may influence the hypotheses and in particularly other cost parameters.

These recurrent costs are linked to the need for this renewal process which, outside of data collection, can prove difficult without internal management of the planning process, and sometimes entails the need to resort once more to the services of an external supplier.

Several countries find themselves back where they started, only few years after heavily investing in the creation of a rural electrification development plan, due to a slight modification in the planning parameters or a minor logistic detail, which could prove nevertheless disastrous: changes in the administrative boundaries, a decision on a change of land-use management, an increase in fuel prices, a change in the national electricity company's development plans, a modification in the pricing policy or the subsidisation policy, losses of source files or a computer crash, a change of team, etc.

Thus, sometimes the plans developed have been of little or no use, and the institutional Planner is unable to update them.

1 6 3 Comparative advantages of internal management of planning tools

As mentioned previously (cf. section 2.5.3), internal management of the use of a computer tool for rural electrification planning (expert system or decision-making) has several advantages, among them:

- Enabling the planner to easily perform a large number of sometimes complex and tedious calculations;
- Enabling, in particular, the rapid testing of various scenarios (a simulation known as digital) and the conducting of sensitivity analysis on a simplified modification of certain parameters;
- Enabling work to be easily carried out on different territorial scales, when the tool includes a geographical dimension (Geographic Information System), as it is increasingly the case.
- Enabling planning results to be output and in particular making it possible to easily extract investment programmes.
- Etc.

The initial investment costs therefore relate only to the acquisition of the tool and training in its use, as well as the data collection required for input. The recurrent costs include the renewal of licences, and after-sales service (maintenance, upgrading, etc.). It is important, however, to select a tool based on concepts in line with one's own view of rural electrification development (cf. section 2.5) or sufficiently flexible to include them. This tool should as far as possible meet the planning objectives set by one's Government (cf. section 2.2), offer the best quality-price ratio, and have a sustainable after-sales service.

How much does it cost?

Unfortunately, rural electrification planning could prove prohibitively costly if the necessary recurring revisions and the options for easily performing various simulations are not properly planned. These costs basically include fees for gathering socioeconomic, technical and economic data, as well as the cost of expertise, whether internal or external, associated with the processing and analysis of this data. The processes used for sharing multi-sector data can very significantly lower the costs associated with data collection and revision.

The revision of planning results – which are furthermore very sensitive to changes in parameters and calculation hypotheses – and of investment programming, requires frequent renewal and an internal appropriation of planning processes.

Managing a rural electrification planning tool can be a sustainable alternative to the repeated and costly use of external expertise. However, the tool must be adaptable to the sovereign vision and objectives of rural electrification planning, and must be able to show good quality-price returns over the long term.

1 7 Why do we plan?

In general terms, planning consists in anticipating in a precise field, the various measures associated with a project, in light of specific objectives to be attained, constraints to overcome, and clear-cut means (human, material and financial) over a determined period.

A rural electrification planning exercise is justified first and foremost by its ability to validate the feasibility of the rural electrification strategy (the pre-planning stage), while at the same time providing a concrete response, before engaging in the more operational phase of investment programming. This involves the optimisation of resources, and in particular of financial resources, enabling the objectives of access to electricity throughout a given rural territory to be achieved within a given horizon, as set in the strategy documents.

From this perspective, the need to plan is necessary due to the structurally unprofitable nature of rural electrification, and consequently requires the implementation of public subsidisation in situations where resources are often limited.

Moreover, the opening to private sector participation encourages the use of rural electrification planning as a tool for transparency and visibility, concerning investment risks and opportunities for potential operators.

Lastly, planning results can also be used as an argument in favour of corrective measures intended to accelerate the growth of rural electrification, given the existing regulatory framework (promotion of renewable energy, technical norms, specific taxation, pricing policy, conditions for third-party access to the network, etc.).

Why do we plan?

The aim of rural electrification planning is to fulfil the general objectives defined by the sectoral strategy, for example, maximisation of access to electricity within a given territory and within a given time horizon, for a specified level of subsidisation: a sovereign process in which it is increasingly important to include features for territorial planning and for strengthening the economic and social impact of rural electrification.

This exercise helps to validate the feasibility of the objectives set, and paves the way for the more operational phase of investment programming. This is an instrument for transparency and visibility within the sector, particularly for private operators.

The planning results can also be used as an argument in favour of corrective measures intended to accelerate the growth of rural electrification, in view of the existing regulatory framework (a policy favouring renewable energy, technical standards, taxation, pricing policy, conditions for third-party access to the network, etc.).

2

State of the art

The classification of the current planning methods into homogeneous categories is an inevitably simplifying exercise. It is in fact common to find approaches bordering the various categories proposed below, especially since the responses provided for the various issues mentioned in the previous chapters can be varied. Nevertheless, the distinction between “demand-based” and “supply-based” seems relevant, and will therefore be the main distinguishing factor in this analysis.

2 1 Typology of current methodologies

2 1 1 Supply-based approaches

A Method description

A typical example of supply-based planning methodology is the planning for grid expansion conducted by electricity companies. These are detailed studies for the purpose of costing and optimally sizing the transport and distribution network as well as the production, in view of imminent investments. Although a conceptual distinction is made between conventional electricity systems and rural electrification, in actual fact, the planning of grid expansion eventually affects rural areas and it is thus worth to be mentioned in this state-of-the-art. This kind of planning is often segmented into several interdependent exercises, corresponding to the various components of the electricity infrastructure:

- **Resource planning (production):** this seeks to identify less costly options for satisfying the growth in demand over time. It is based on complex optimisation tools such as the Wien Automatic System Planning Package (WASP) or the Jiaotong Automatic System Planning Package (JASP). While resource planning has traditionally been concerned exclusively with options linked to centralised electricity production, these tools are now designed to study decentralised sources as well as the alternatives affecting demand (energy efficiency, consumption reduction) and take into account the costs of the demand not met for the national economy (outage costs): this is the integrated resource planning. However, these are still "supply-based" type models in the sense that the demand is only taken into account as a time series ("top-down" modelling) and is therefore implicitly constrained by supply (the existing electricity infrastructure), since rural demand is not considered a datum or a specific objective. On the other hand, most of these models are only designed for centralised production plants whose size is not proportionate to demand in the rural areas.

  Resource planning can also be done outside the framework of the national electricity company, in order to define elements of rural electrification policy such as potential alternative energy sources or the impact of new regulations. These studies are naturally conducted further up-stream (since the objective is not to identify investment projects), and are conducted exclusively by the decision-makers. The methods used can be the same as those used by electricity companies (integrated resource planning), or they can be based on isolated cases studies (fictional or otherwise) so that the results can then be extrapolated at country level. This latter method is more appropriate to a decentralised and off-grid approach to rural electrification.

- **Transport planning:** not very relevant to rural electrification in most cases, due to the low energy it uses.

- **Distribution planning:** concerns the optimisation of distribution lines and the positioning of substations, using detailed modelling tools mostly having a spatial component (transmission calculations, voltage drops, constraints of the terrain...). This exercise is indeed closer to design studies than long-term planning, but it can be preceded by an identification and a hierarchical organisation of candidate localities according to socioeconomic or political criteria, which moderate the "supply-based" nature of the approach. Such is for example the case in Thailand (P. Yalamas, 2003) where emphasis is being placed on grid expansion and the rapid increase of coverage levels by implementing various programmes, based on the hierarchical logic of specific localities:

  - Population/distance from grid ratio
  - Administrative status (administrative centres and priority adjacent localities)
  - Part of investment borne by the locality

- Multi-sector process:

- The number of villages to be supplied with electricity in each province is determined according to 30 aggregate socio-economic indicators at the provincial level
- Idem at the regional level with other indicators
- Lastly, the localities are classified according to 7 equally-weighted criteria: distance from the grid, distance to the roadway, population, anticipated number of customers, kW equivalent in production usage, number of commercial activities, and number of infrastructures.

B Examples of application

- Assessment of the impact of a carbon tax on power-generation systems and on the emissions' reduction in Vietnam (Limmeechokchai et al, 2003). The WASP method was used.
- Master Plan for rural electrification in Cambodia, using renewable energy (JICA, 2006). This is a large-scale assessment of the potential of renewable energies, based in part on a GIS, area surveys and more detailed pre-feasibility studies (hydro and biomass projects).
- Assessment of the potential for biomass gasification for rural electrification in Laos (LIRE, 2008). This study consists in envisaging various imaginary situations of electrification by biomass gasifiers (rice husks), in order to determine the most effective modalities for implementation and the relevance of this solution in general terms for the rural areas in the country.
- Ascertainment of the potential for production from biomass in South Africa, using GIS tools (DME, 2004). To accurately assess the potential use of residues from logging and sugar cane throughout the territory, a project design tool was used in conjunction with a GIS.

2 1 2 Demand-based approaches

A Method description

The first example of a demand-based approach is the creation of technological "packages" for targeting a specific demand (healthcare, education, production usage, security, comfort...). This approach consists in ascertaining the technical and economic relevance of a small-scale solution, so that its large-scale replication can then be promoted (similar to the studies of potential mentioned in the previous section, except that in the present case the main focus is on the demand rather than supply). The study is therefore frequently based on pilot projects and case studies. The ENABLE project has for example conducted electrification planning for health, education, and water supply services based on small renewable systems (EIE-ADEME, 2007).

Another more widespread example, which covers an important part of the planning methods used, is the identification of projects within a given territory, in a perspective of land-use management (integrated territorial planning). The objective here is to practically and expediently determine the best options for electrification with a minimum of technological (renewable/fossil energy, on/off-grid) and ideological (centralised/decentralised) bias by focusing on the most relevant uses of the service in a rural environment. This approach is, therefore, strongly multi-sector based since it solicits the various rural development actors as well as the electricity company/companies. The general process often involves proceeding in 3 consecutive stages:

1. Identifying, either in consultation with the grid operators or not, the localities likely to be connected to the grid in the near future;

2. Identifying the decentralised projects from the available energy (diesel, small hydroelectric plants, biomass, wind, etc.) and financial resources. These projects are selected and hierarchically arranged according to criteria which could potentially have an impact on social and economic development.
3. Proposing decentralised rural electrification solutions (PV, multi-functional platforms[32]) in order to ensure access to basic energy services in the remaining localities.

The result is, thus, a mix of solutions adapted to local contexts, which can result in more detailed studies (prefeasibility, feasibility).

B Examples of application

- **Planning in South Africa:** the approach considers grid expansion (SWER) as the main means of electrification with complementary decentralised projects. An innovative cost-benefit model has been developed, which adapts the conventional concept of project benefits (number of kWh sold) to the "demand-based" approach: the kWh are weighted according to the uses they serve, e.g. 1 domestic kWh is worth 1 point while 1 kWh for a clinic will be worth 25 (Banks et al, 2000). Secondly, the economic impact of electrification is also measured at the macro level (regional and national)
- **The rural electrification Master Plan in Ethiopia**, project MEPRED ("Mainstreaming Energy for Poverty Reduction and economic Development)" in Burkina Faso, project CAP REDEO ("Capacity and institutional strengthening for Rural Electrification and development, Decentralised Energy Options") in Laos and Cambodia, project IMPROVES-RE ("Improving Economic and Social impact of Rural Electrification") in Burkina Faso, Cameroon, Mali and Niger: formulation of a planning methodology intended to maximise the potential impact of rural electrification on social and economic development. The innovative aspect of this approach lies in its Development poles/Hinterlands model for analysing spatial dynamics; this model hierarchically arranges the localities to be supplied with electricity based on the potential for economic and social influence of their infrastructures.
- **The Global Rural Electrification Programme (PERG) in Morocco:** network solutions, mini-networks and ERD (decentralised rural electrification) have been studied throughout the territory in order to electrify at lower cost[33] the entire territory in a short time (without particularly targeting production or social usage in the first instance[34]). The results of the lower-cost analysis have been corrected in order to maintain a balance between the regions in the country in terms of network coverage (S. Boutayeb, 2002).

2 2 Computer planning tools

A few examples of tools (for which specifications are available), are provided below and grouped into 3 categories:

- Design of production options
- Network design
- Territorial planning

[32] Although the platform basically supplies mechanical instead of electric power, the latter has a part to play in a "demand-based" approach since it involves primarily energy services.
[33] The model is based among other things on intra-village dispersal (average distance between households) and inter-village dispersal in order to calculate investment costs per subscriber.
[34] It is important to note that the National Electricity Office ONE) is presently in the process of formulating an electrification assessment strategy, so as to encourage usage having high potential for development

The first two categories of tools are primarily intended for feasibility studies, but can be used, if necessary, as elements of a more comprehensive planning methodology (furthermore, some of these tools, such as ViPOR and HOMER, are capable of communicating with each other).

2 2 1 Design of production options

There are numerous design tools for renewable or hybrid energy systems. Among the most widely used are:

- HOMER (www.homerenergy.com or analysis.nrel.gov/homer/), developed by the National Renewable Energy Laboratory (NREL) in the united States;
- RETScreen (www.retscreen.net), developed by the Division of Electric Power and Natural Renewable Resources of Canada (NRCan).

A HOMER

Homer is a tool for assessing stand-alone or interconnected electric systems, available free of charge on the internet website shown above. It allows evaluating the technical and economic feasibility of renewable or non-renewable technological options (PV, wind turbines, small hydroelectric plants, power generators, biogas, fuel cells, etc.). Energy storage is also taken into account.

The South Africa Department of Minerals and Energy is seeking to couple HOMER with a GIS in order to automate the evaluation of the potential of biomass within a territory, using data on potential, available in GIS format (DME, 2004).

B RETSCREEN

RETScreen is a similar tool which is also available free of charge. Many technological solutions can also be considered for production of both electricity and heat. The software has detailed databases for retrieving default cost and performance values, as well as meteorological data on several global locations (for the power sources depending on it). The financial analyses are able to integrate the Clean Development Mechanism (CDM).

2 2 2 Network design

Similarly, there are numerous software programmes for computing the design and optimisation of medium and low-voltage electricity power networks.

Two examples of software dedicated to rural electrification (design of plans for communities using low and medium-voltages with options for decentralised production):

- LAP (www.systemseurope.be/products/lap.fr), developed by Systems-Europe/EDF ;
- ViPOR (analysis.nrel.gov/vipor/), developed by the NREL.

A Low voltage electrification Analysis and Planning (LAP)

LAP is a supporting software programme for Low-Voltage distribution projects. After computation of the electrical aspects of the power network (current, voltage, drops, etc.), LAP determines the list of required investments. Taking into consideration the costs of these investments and of the operation of the power network on the one hand, and the revenues which will result from the sale of services on the other hand, LAP produces an optimised economic evaluation. The results obtained for several power distribution networks can be consolidated to produce an overall economic evaluation for a region. The software programme has GIS functionalities and is able to factor in various energy sources: diesel, wind, small hydroelectric plants, solar power systems, and network interconnection.

B The Village Power Optimization model for electric Renewables (VIPOR)

ViPOR is an optimisation model for village electrical power systems. Using the map of a village and information on the size of the loads and the cost of equipment, ViPOR determines which households must be supplied by stand-alone systems (e.g. PV) and those which must be included in a centralised distribution network. The distribution network is optimally designed taking account of territorial constraints.

C More generalised software programmes

A few examples of more generalised software programmes (used on large electrical power systems):

- NEPLAN, (www.neplan.ch), Power System Analysis and Engineering, developed by BCP (Busarello+Cott+Partner Inc.);
- GIPSY, software for the design and planning of electric power grids. Developed in 1996 by the Belgian company, Algorithme (http://www.algo.be/dev-logiciels.htm#exp) and used by Tractebel Engineering (TEE, http://www.tractebel-engineering.com/) since 1996;
- POWERWORLD simulator (www.powerworld.com), developed by Powerworld corp.

2 2 3 Planning on a territorial scale

While there is an abundance of tools dedicated to design and feasibility studies, integrated planning tools are still scarce, undoubtedly due to the non-systematic nature of the methodologies used, and the limited demand for easily revisable rural electrification plans.

Here are some examples of tools for conducting long-term planning on a given territory:

- «Electrification Planning Decision Tool», developed by Rural Areas Power Solutions (RAPS);
- LAPER, Logiciel d'Aide à la Planification d'Électrification Rurale (rural electrification planning software tool) developed by EDF R&D and Systems Europe (www.systemseurope.be/products/laper.fr.php);
- SOLARGIS, Integration of renewable energies for electricity production in rural areas (www-cenerg.cma.fr/~st/solargis/), developed by the Centre d'Énergétique (CENERG) – ARMINES (France);
- ENERGIS, Regional Energy Planning using GIS technology, developed by INESC (Instituto de Engenharia de Sistemas e Computadores, http://www2.inescporto.pt/);
- LEAP (www.energycommunity.org/default.asp?action=47), developed by the Stockholm Environment Institute in Boston;
- GEOSIM (www.geosim.fr), developed by Innovation Energie Développement (IED).

A Electrification Planning Decision Tool

This tool was specifically designed for the planning of rural electrification in South Africa, and does not appear to be available to the public. The model is, nevertheless, given a brief introduction in section 3.1.2 and a more detailed presentation in (Banks et al, 2000). Computational algorithms use a GIS database to extract the most relevant options for each locality (grid expansion, mini-power networks, PV systems), with the projects hierarchically arranged according to their socio-economic impact (quantified in terms of kWh distributed, weighted differently depending on usage) over cost ratio. Another tool is then used to conduct an analysis of the macroeconomic impact on the regional and national economies.

A subsequent adaptation of the tool has implemented an algorithm for medium-voltage line transmission routes, which takes account of territorial constraints.

B Rural electrification planning software (LAPER)

LAPER calculates the most economical masterplan for electrification of an area not yet supplied with electricity. LAPER, first of all, determines the villages which would economically benefit from being connected to the power grid and those for which a decentralised method of electrification is preferable. After this computation of the "target" solution, LAPER determines the master plan based on given annual budgets and various non-technical criteria (political, environmental, ...) which influence the order in which villages will be electrified.

The software is based on a GIS (ArcView from ESRI).

C Integration of renewable energies for electricity production in rural areas (SOLARGIS)

The purpose of this GIS-based (ArcView from ESRI) software is to identify lower-cost options for rural electrification of various locations in the territory; these options include solar, wind, diesel, diesel/wind hybrids, and the power grid.

D Regional Energy Planning using GIS technology (ENERGIS)

ENERGIS has been developed by INESC (Instituto de Engenharia de Sistemas e Computadores) of Porto in Portugal, and its design/function is similar to that of the SOLARGIS software.

E Long-range Energy Alternatives Planning (LEAP)

The objective of the LEAP system is to define long-term energy and environmental scenarios for a given territory, going from exhaustive compatibility of energy use, conversion, and production. The planner can, in this way, test numerous technological, economic, demographic, pricing, and other scenarios in order to see how they influence the supply/demand balance, environmental resources, and greenhouse gas emissions.

Unlike the other software programmes outlined in this section, LEAP does not use spatial (GIS) functions and is not used for the purpose of identifying electrification projects.

F GEOgraphic SIMulation for rural electrification (GEOSIM®)

The GEOSIM platform is an integrated tool based on a GIS (Manifold). Its main innovation consists in the optimisation of energy services covering a given territory, within a given time horizon, with a view to improving the economic and social impact of rural electrification. Consequently, as it is based on the logic of land-use management, GEOSIM is initially used to select and hierarchically arrange the localities according to their own dynamism and impact on neighbouring localities (introduction of the concepts of Development Poles and hinterlands).

Next, once demand forecasting has been completed within the planning horizon, the various electricity supply options (including connection to the power grid and decentralised solution such as hydroelectricity, biomass and power generators) are obtained within regard to technical-economic optimisation.

The GEOSIM furthermore offers the planner the possibility of introducing various temporary solutions for generalised accessed to basic energy services, in the localities which are isolated from development poles and which do not benefit from conventional electrical power systems within the planning horizon: this, ultimately, enables the territory to be systematically covered by modern energy systems.

G Other tools

Other tools have also been identified, without providing detailed information:

- GIS'ELEC, created as part of a thesis by C. Lamâche (EDF): a planning tool based on a GIS;
- NORIA, developed by Fondation Energies pour le Monde: according to a brochure on the RESIREA project, "NORIA" is used to examine the long-term feasibility of ERD (decentralised rural electrification) projects involving 10 to 100 villages in order to:
  - Develop the renewable energy sector in developing countries and facilitate its establishment by private operators and investors;
  - Identify the most favourable areas based on technical, economic, financial, political, institutional, geographical, and social criteria;
  - Target, within these areas, the villages which meet the criteria required for the implementation of programmes that are both sustainable and independent financially and technically;
  - Ascertain the technical, financial, and organisational options suitable for each village; submit the details on the financing, implementation, and operation of the plants to donors and operators.

3

State of affairs

Which are the Rural Electrification methodologies and planning tools used by CLUB-ER members ? This chapter is a summary of the outcomes of a survey carried out among CLUB-ER members in 2008.

3 1 General statistics from responses to the questionnaire

13 Countries and 16 institutions were surveyed using a questionnaire. The response rate is relatively satisfying since it is 77% for the countries and 69% for the institutions. The following agencies responded:

- Agency for Rural Electrification Development (ADER, Mauritania)
- Rural Electrification Unit (CER, Niger)
- Energy Division (DGE, Togo)
- Electrification Development Fund (FDE, Burkina Faso)
- Benin Agency for Rural Electrification and Energy Management (ABERME, Benin)
- Ivory Coast Electricity Operators (SOPIE, Ivory Coast)
- Electricity Sector Development Fund & National Agency for Rural Electrification (FDSEL & ANER, Congo-Brazzaville)
- National Commission on Energy (CNE, Democratic Republic of Congo-DRC)
- Energy Division (DGE, RCA)
- Electricity Sector Regulatory Agency (ARSEL, Cameroon)

Included among these entities are:

- 3 Structures directly attached to the Ministry in charge of Energy
- 3 rural electrification Agencies
- 2 rural electricity funds
- 1 public investment project supervisor in the electricity sector (SOPIE)
- 1 Regulator
- 1 Commission

3 2 Methodologies in current use by CLUB-ER members

3 2 1 "Supply-based" approaches, but with elements of land-use management

While most of the methodologies currently being used to plan rural electrification are essentially "supply-based" with a technical-economic approach, it should still be noted that non-technical-economic criteria are very often used in selecting localities to be supplied with electricity (essentially the demographic weight, administrative status and distance from the grid).

As a consequence, except for the National Energy Commission (Congo-Kinshasa), which seems to consider only technical-economic factors (ability to pay, budgetary constraints per locality and household dispersion) in its five-year plan[35], several countries propose priority targeting of localities based on administrative and demographic criteria:

- CER - Rural electrification unit (Niger): all administrative capitals and localities of over 3000 inhabitants;

[35] These plans are not specifically rural electrification plans (in actual fact, a very small proportion of the localities concerned are located in rural areas), which may explain the essentially technical-economic approach.

- DGE – Energy Division (Togo): remote localities of over 5000 inhabitants, or else proximity to the power grid and to roads;
- ABERME – Benin Rural Electrification & Energy Management Agency (Benin): while the list of priority localities is defined by the Ministry in charge of Energy, actual implementation depends on the solvency of the demand (co-financing by local authorities and the direct participation of at least 25% of the households by means of internal cabling of their houses and prepayment of connection costs);
- ADER - Agency for Rural Electrification Development (Mauritania): planning, additionally, takes into account the stability of the region and the solvency of the demand;
- FDE - Electrification Development Fund (Burkina Faso): planning is also an attempt at geopolitical balance and takes a pragmatic approach by taking into consideration the criteria specific to potential donors.

These various approaches often define administrative status (Main Towns, Rural Communes) and population thresholds as criteria for identifying priority localities. The distance from the power grid is used as an additional selection tool and/or an element of choice for the electrification solution proposed (connection to the grid or a decentralised system).

3 2 2 A tendency towards openly "demand-based" approaches

Three countries, characterised either by having recently entered the sphere of influence of electricity sector reform (Congo-Brazzaville, CAR), or by having reconsidered the hypotheses by which their primary strategic choices have been guided (Cameroun)[36], wish to formulate a planning methodology with a slant towards a multi-sector "demand-based" approach.

Similarly, countries having already initiated planning processes are looking to strengthen the "demand" dimension of their approaches.

Included among these is Niger (CER, the rural electrification unit) which is seeking to better integrate upstream the socio-economic impact of rural electrification in its planning process, particularly by taking into account the social and economic infrastructures in the localities.

Likewise, Burkina Faso recently finalised regional planning for rural electrification as part of the MEPRED project, and this was very heavily oriented towards the demand for an energy service. The training of local and central actors was one of the main components of the project in view of national appropriation.

3 2 3 Limited involvement in the design of projects

Only two structures out of those responding have planning activities entirely dedicated to the design of works:

- ADER - Agency for Rural Electrification Development (Mauritania): the agency conducts design studies and prepares invitations to tender for rural electrification projects;
- SOPIE – Ivory Coast Electricity Operators (Ivory Coast): SOPIE is planning the expansion of the electricity service in the Ivory Coast with an electricity approach (design of distribution networks, grid designs).

The responsibilities these two agencies have for investment programming and project management or contract management has certainly influenced the planning approach chosen.

[36] A Programming and Planning Committee steered by the Ministry of Energy and Water Resources, will now support the activities of the Rural Energy Fund which will be newly created.

3 3 Tools available from CLUB-ER members

For the purposes of their studies on design and feasibility of works, SOPIE (Ivory Coast) and ADER (Mauritania) use tools for economic and financial analysis, grid design and Computer-Aided Design (CAD).

The tasks of demand forecasting and economic and financial analysis are normally performed in a spreadsheet programme (Microsoft Excel). Certain dedicated spreadsheet models are sometimes used (ADER uses MATILDE for its economic and financial analyses).

SOPIE executes its grid designs using NEPLAN, and the CAD is done is both instances using Autocad.

Except for these various tools which perform specific tasks (quite outside of the planning exercise), no integrated planning tool has been mentioned with the exception of GEOSIM® which is installed and in the phase of appropriation in Burkina Faso, Cameroon, Congo, the Central African Republic and Chad, as part of the MEPRED and CEMAC Energy Facility projects.

The GIS tool is available in only a few countries, the need for training in this area is frequently expressed.

Conclusions and Recommendations

4

4 1 A paradigm shift since the early 2000s

The current methodological approaches and general trends in rural electrification planning can be explained by a rapid background review of rural electrification.

Traditionally, this activity was carried out by vertically integrated national electricity companies, i.e., providing all of the services connected with this sector. Naturally, this is because the first models for rural electrification planning were simply an extension of the models used in the planning of conventional electricity systems, with or without adaptations, particularly on technologies, norms and standards.

On the eve of the reforms which were going to shake the institutional landscape of the electricity sector in sub-Saharan Africa from the end of 1990s, these methods of planning and development of the electricity service were considered particularly ineffective and not as high as the stakes in the sustainable development of the rural regions of the planet, kept outside of the traditional energy networks. Thus, in 1995, the Marrakech Summit on "sustainable development of rural environments: Decentralised Electrification" not only sanctioned this concept of "Decentralised Rural Electrification" (ERD), but most of all aimed to encourage a scaling in decentralised electrification matter.

The decade that followed the Marrakech summit showed that while the concept of ERD deserved credit for wider promotion of solutions for off-grid electrification, particularly those developed from renewable energy (solar, hydroelectricity, biomass, wind, etc.), it mistakenly crystallised the opposition between two components of rural electrification development, though they are complementary. Additionally, the technological, economic and financial limitations of the models upon which this ERD scaling is built were able to be highlighted when an evaluation of the programmes following this quasi-ideological impetus was performed. The concept has furthermore evolved since then, as the "D" relates more to an organisational dimension (systems management plans) than to a technological spin-off (everything except the interconnected power network)[37].

Outside of these on-grid/off-grid or centralised/decentralised divides, which no longer seem relevant, a paradigm shift of a different kind is currently being witnessed, especially since the 2002 global summit on Sustainable Development in Johannesburg, and the defining of the Millennium Development Goals (MDG): this is the progression from a "supply-based" approach to a "demand-based" approach.

This transition is the result of the liberalisation of the electricity sector, sometimes accompanied by the privatisation of national electrification companies. This tends to increase the number of actors and thus decentralise the management of the electricity service, which is consequently more in keeping with the demand. Unlike the national electricity companies which were initially vertically integrated and which had substantial financial capabilities, the new stakeholders (agencies and structures in charge of rural electrification) are nowadays more dependent on public resources and even international cooperation, and are more accountable with regard to the impact of rural electrification on development.

4 2 Recommendations for improved planning

Research on the best solutions for energy access within a rural territory should be similar to a kind of combinatorial analysis, with each territory offering a different mosaic of technological solutions apart from its natural specific features, socio-economic limitations, political environment, etc.

[37] The purchase of MV energy on the EDM-SA grid in Mali or on the grid of the Burkinabé National Electricity Company (SONABEL) in Burkina Faso and its distribution by an independent operator is today considered as DRE.

Therefore, bearing in mind the justification for a rural electrification planning exercise, namely optimisation of access to electricity in a given territory within a given time horizon, a few accepted principles must now necessarily be considered:

- Consideration of the ultimate goal, which is the economic and social impact of electricity territory-wide, and which goes beyond electricity to land-use management issues;
- Technological neutrality and real costs in the optimisation of options for electricity supply, unless priority is specifically indicated for a particular technology in national sectoral policy: for example, for matters relating to the promotion of local resources, the development of a technological sector, or even for the promotion of options for a better quality of service;
- The need for a minimum of access to energy services for the development of certain areas within the territory, including the consideration of relatively higher subsidies.
  - Furthermore, owing to the specific characteristics of rural electrification referred to throughout the systematic queries by which the analysis has been guided, the sovereignty of States must also be registered as a cross-cutting principle. Indeed, real costs policy argues in favour of a structural imperative of differentiated subsidisation in order to achieve a balance between production, operation and maintenance costs, the ability of users to pay, and an acceptable level of profitability for private operators. Subsidisation as a compulsory requirement consequently engages the government in a central role.
- The State as a planning agent should therefore be able to advisedly "control" the measures taken and planning tools used. From this perspective, it becomes necessary to strengthen the capabilities of the various state structures (agencies and national structures in charge of rural electrification), including the decentralised ones (local authorities) now involved in the rural electrification planning process. This along with the management of the planning tools respecting the principles above, and authorizing easy updates.
- In order to be more effective, the State must beforehand clarify its responsibilities in relation to (i) the creation of the sectoral strategy, (ii) rural electrification planning, and (iii) investment programming.

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