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Inclui Resumo Executivo em Português

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List of Abbreviations

A	Ampere
ABEER	Associação Brasileira de Empresas de Energias Renováveis / Brazilian Association of Renewable Energy Enterprises
ABRADEE	Associação Brasileira de Distribuidores de Energia Elétrica / Brazilian Association of Electric Energy Distribution Enterprises
AC	Alternating current
ADENE	Agência de Desenvolvimento do Nordeste / Brazilian Development Agency for the Northeast
AGERBA	Agência Estadual de Regulação de Serviços Públicos de Transportes, Energia e Communicações da Bahia / Bahia State Agency for the Regulation of Public Transport, Energy and Communication Services
Ah	Ampere hour
AL	Alagoas / Brazilian state of Alagoas
ANEEL	Agência Nacional de Energia Elétrica / Brazilian National Agency for Electric Energy
ART	Anotação de Responsabilidade Técnica / Technical Responsibility Certificate
BA	Bahia / Brazilian state of Bahia
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung / German Federal Ministry for Economic Cooperation and Development
BN	Banco do Nordeste
BNDES	Banco Nacional de Desenvolvimento Econômico e Social / Brazilian National Economic and Social Development Bank
BOS	Balance of system
CAR	Companhia de Desenvolvimento e Ação Regional, Bahia / Regional Development Company, Bahia
CCC	Conta de Consumo de Combustíveis / Fuel consumption account
CDE	Conta de Desenvolvimento Energético / Energy development account
CDM	Clean development mechanism
CEAL	Companhia Energética de Alagoas / Energy Company of Alagoas
CEMIG	Companhia Energética de Minas Gerais / Energy Company of Minas Gerais
CEPEL	Centro de Pesquisa de Energia Elétrica / Electric Energy Research Center
CERB	Companhia de Engenharia Rural da Bahia / Rural Engineering Company of Bahia
COELBA	Companhia Elétrica da Bahia / Electricity Company of Bahia
CREA	Conselho Regional de Engenheiros e Arquitetos / Regional Council for Engineers and Architects
DC	Direct current
DF	Distrito Federal / Federal District of Brasília
DIE	Deutsches Institut für Entwicklungspolitik / German Development Institute

EMATER	Empresa de Assitência Técnica e Extensão Rural / State Company for Technical Assistance and Rural Development
ESMAP	Energy Sector Management Program
FAO	Food and Agriculture Organization of the United Nations
GDI	German Development Institute
GEF	Global Environment Facility
GHG	Greenhouse gas
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit / German Corporation for Technical Assistance and International Cooperation
HDI	Human Development Index
IADB	Interamerican Development Bank
IBGE	Instituto Brasileiro de Geografia e Estatística / Brazilian Institute for Geography and Statistics
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
INCRA	Instituto Nacional de Colonização e Reforma Agrária / Brazilian National Institute for Colonization and Agrarian Reform
INMETRO	Instituto Brasileiro de Normas Técnicas / Brazilian Institute for Technical Norms
KfW	Kreditanstalt für Wiederaufbau / German Development Bank
kW	Kilowatt
kWh	Kilowatt hour
MAPA	Ministério da Agricultura, Pecuária e Abastecimento / Brazilian Federal Ministry for Agriculture and Food
MDA	Ministério do Desenvolvimento Agrário / Brazilian Federal Ministry for Agrarian Development
MEC	Ministério da Educação / Brazilian Federal Ministry for Education
MG	Minas Gerais / Brazilian state of Minas Gerais
MINA	Ministério da Integração Nacional / Brazilian Federal Ministry for National Integration
MME	Ministério de Minas e Energia / Brazilian Federal Ministry for Mines and Energy
NGO	Nongovernmental organization
O&M	Operation and maintenance
ONG	Organização Não-Governamental / Nongovernmental organization
PERMER	Proyecto de Energía Renovable en el Mercado Eléctrico Rural / Project for Renewable Energy in the Rural Electricity Market (Argentina)
PM	Project management
PRODEEM	Programa de Desenvolvimento Energético de Estados e Municípios / Energy Development Program for States and Municipalities (Brazil)
PV	Photovoltaic

PVS	Photovoltaic system
RAPS	Rural area power solutions
RET	Renewable energy technologies
RGR	Reserva Global de Reversão / Global Reversion Reserve
R$	Brazilian real (currency)
SEED	Solar electric energy delivery
SEI	Superintendência de Estudos Econômicos e Sociais da Bahia / Superintendency of Economic and Social Studies of Bahia
SEINFRA	Secretaria de Infraestrutura da Bahia / Bahia State Infrastructure Secretariat
SELCO	Solar electric light company
SF	Sistema fotovoltaico / Photovoltaic system
SFD	Sistema fotovoltaico domiciliar / Solar home system
SG	Solar generator
SHS	Solar home system
SLI Battery	Starting lighting ignition battery
TV	Television
UFBA	Universidade Federal da Bahia / Federal University of Bahia
UFRJ	Universidade Federal do Rio de Janeiro / Federal University of Rio de Janeiro
UNCHS	United Nations Conference on Human Settlements
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNIFACS	Universidade Salvador / University Salvador
US $	United States dollar
USP	Universidade de São Paulo / University of São Paulo
V	Volt
VCR	Video cassette recorder
W	Watt
WB	World Bank
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderung / Academic Advisory Council of the German Federal Government for Global Environmental Change
WEA	World Energy Assessment
Wp	Watt peak

Resumo Executivo

Proteção ambiental e climática, assim como, a necessidade de implementar sistemas sustentáveis de fornecimento de energia são temas de grande importância na atual cooperação para o desenvolvimento. Um outro desafio central para a cooperação visando o desenvolvimento é o fornecimento de infra-estrutura básica para a população pobre. A falta de serviços básicos de infra-estrutura é destacada, especialmente, nas áreas rurais, onde vive a grande maioria da população pobre do mundo. Graças ao progresso tecnológico, tecnologias de energias renováveis são soluções cada vez mais atrativas para o fornecimento de energia no meio rural. Isso se refere especialmente à tecnologia fotovoltaica solar que recentemente tem sido mais e mais usada em sistemas chamados de sistemas fotovoltaicos isolados (SFs) para abastecer áreas com densidade populacional baixa, sem acesso à rede elétrica nacional.

A atratividade do uso de SFs para o fornecimento de energia no meio rural se baseia na possibilidade de alcançar, simultaneamente, metas ambientais, econômicas e sociais: Por um lado, o desenvolvimento rural pode ser promovido fornecendo energia elétrica para uma maior parte da população rural numa maneira economicamente viável. Por outro lado, efeitos ambientais negativos relacionados ao uso de tecnologias convencionais podem ser evitados. Porém, experiências de diferentes países em desenvolvimento indicam que vários projetos de tecnologia fotovoltaica não alcançam uma sustentabilidade técnica e financeira e não realizam os possíveis benefícios de maneira satisfatória.

Esta pesquisa apresenta uma orientação para a cooperação visando o desenvolvimento em relação às melhores práticas para promover o fornecimento sustentável de eletricidade através de SFs, baseado num estudo de caso no Brasil. Três problemas centrais foram analisados para avaliar a sustentabilidade e os benefícios de projetos de SFs: i) as condições setoriais (legais, econômicas e políticas) para a eletrificação rural através de SFs (nível macro); ii) as exigências em termos de gerenciamento de projetos, quer dizer, relativas a assuntos organizacionais e financeiros para alcançar uma sustentabilidade técnica e financeira (nível micro); iii) os impactos de projetos de SFs no desenvolvimento rural.

O contexto para o uso de sistemas fotovoltaicos para a eletrificação rural em países em desenvolvimento

Opções técnicas: Existem principalmente duas alternativas técnicas para o fornecimento de energia em áreas rurais. A primeira é a extensão da rede nacional e a segunda é a geração de eletricidade independente da rede (isolada). Recentemente, tecnologias de energia renovável são utilizadas mais freqüentemente para a geração isolada, competindo assim com o uso do gerador diesel ou a extensão da rede. A competividade relativa das diferentes tecnologias para fornecer eletricidade rural depende, por um lado, das condições climáticas e geográficas (especialmente no caso das energias renováveis), por outro lado da densidade do consumo de eletricidade (kWh/km^2/mês) da área a ser abastecida. SFs são competitivos em áreas com densidade de consumo muito baixa (quer dizer, áreas com densidade populacional e consumo baixos de eletricidade por família). Como regra geral, os custos médios do fornecimento de eletricidade aumentam com a diminuição da densidade de consumo, visto que os efeitos de escala diminuem. Isso significa, que tanto menor é a densidade de consumo, quanto maior é o custo médio.

Características sócio-econômicas da demanda: As regiões alvo aptas à eletrificação através de SFs em países em desenvolvimento, quer dizer, regiões de baixa densidade de consumo, normalmente apresentam altas proporções de famílias com renda e nível de educação baixos. Isso significa, por um lado, que a capacidade de pagar é comumente baixa demais para cobrir os custos totais de qualquer tecnologia (mesmo de menor custo) para o abastecimento e, portanto, a demanda não pode ser atendida no âmbito do mercado. Esta situação pode ser considerada como um caso de fracasso do mercado e justifica o uso de subsídios para alcançar a população rural pobre com serviços de energia elétrica, a menos que se limite a abastecer as famílias rurais relativamente ricas. A segunda impli-

cação das condições na região alvo é que, dado os baixos níveis de educação, esforços substanciais em relação à capacitação têm que ser feitas na ocasião da introdução da tecnologia fotovoltaica nestas áreas para garantir uma manutenção adequada. Porém, estas características sócio-econômicas da demanda podem variar consideravelmente entre diferentes regiões e países.

Barreiras institucionais e relativas à informação: SFs enfrentam uma série de barreiras institucionais e relativas à informação típicas da introdução de novas tecnologias. Existe uma deficiência de informação entre a população rural, prestadoras potenciais de serviços e políticos sobre os potenciais da tecnologia fotovoltaica. Isso, junto com uma falta de experiência na gestão e na manutenção de projetos de SFs conduz, muitas vezes, à exclusão da tecnologia fotovoltaica de programas oficiais de eletrificação. Além disso, em muitos países em desenvolvimento faltam padrões de qualidade para componentes nacionais de SFs, o quê leva a uma qualidade de produto não confiável.

Estrutura do setor elétrico: A indústria de eletricidade foi tradicionalmente representada por empresas estatais monopolistas. O desempenho fraco deste modelo organizacional em países em desenvolvimento em termos de qualidade e cobertura de serviços, como também, questões orçamentárias resultantes da falta de sustentabilidade financeira levaram a amplos esforços de reforma apoiados pelas instituições financiadoras internacionais. Estas reformas objetivam a privatização e liberalização de empresas públicas de energia anteriormente administradas pelo estado, levando a uma abordagem baseada no mercado. Este novo modelo organizacional reconfigura as condições para o desempenho do setor como um todo. Parcerias com agentes privados oferecem novas opções, mas também desafios consideráveis para programas de eletrificação rural. Por um lado, atraindo capital e conhecimento privados amplia o campo de ação para abordagens descentralizadas utilizando energias renováveis como os SFs. Por outro lado, a profitabilidade da eletrificação rural pode ser difícilmente alcançada, de maneira que mecanismos eficientes de subsídios e incentivos têm que ser concebidos se o objetivo é atender a parte desfavorecida da população.

Abordagens da eletrificação rural através de sistemas fotovoltaicos

Para encorajar um fornecedor de eletricidade de incluir SFs no âmbito de seus serviços e direcioná-los à população tradicionalmente excluída do acesso à rede elétrica, os seguintes elementos são necessários: i) um modelo adequado de gestão, incluindo mecanismos sustentáveis de financiamento, como também, medidas de informação e de capacitação (nível micro); ii) um regulamento adaptado às necessidades de SFs (nível macro).

Nível micro: No nível micro, um fornecedor de eletricidade tem que tomar a decisão de qual modelo de gestão seria o mais adequado para atender uma área rural através de SFs, considerando o regulamento atual (ver em baixo). Existem duas opções principais: i) o modelo de venda e ii) o modelo de serviço. Relacionado a isso, iii) mecanismos sustentáveis de financiamento, como também, iv) medidas adequadas de informação e capacitação têm que ser oferecidos.

No **modelo de venda**, o *equipamento* de SF é vendido havendo uma transferência de propriedade do vendedor para o comprador. Este modelo pode ser dividido em três sub-tipos: o modelo de venda à vista, o modelo de venda à crédito e o modelo de aluguel com a compra final (*leasing*). Os elementos comuns são que o usuário se torna proprietário do sistema e que o contrato de venda não inclui um serviço de manutenção (porém, os componentes do SF podem ser cobertos por uma garantia do fabricante). Isso significa que a manutenção e a substituição de componentes (especialmente a bateria) têm que ser providenciadas pelo próprio comprador, se ele não fecha um contrato adicional de manutenção com o provedor de serviço.

No **modelo de serviço**, o *serviç*o de abastecimento de energia elétrica é vendido e o equipamento de SF fica na propriedade da empresa fornecedora. Este modelo pode ser dividido em dois sub-tipos: O modelo de pagamento para o serviço (normalmente considerado idêntico ao 'modelo de serviço') e o modelo de aluguel sem a compra final. O elemento comum é que a empresa continua proprietária do SF. O elemento de diferenciação é que o modelo de pagamento para o serviço inclui o aluguel do equipamento, como também, o serviço de manutenção, enquanto o modelo de aluguel sem a compra final inclui somente o aluguel do SF e o serviço de manutenção tem que ser providenciado separadamente pelo usuário.

Mecanismos de financiamento têm um papel decisivo já que a população alvo normalmente não pode pagar os custos consideráveis do investimento do seu bolso (um sistema fotovoltaico domiciliar – SFD – básico com uma capacidade de 50 Wp custa entre US$500 e 1.000), e geralmente não tem acesso fácil ao crédito. Também a cobertura dos custos de operação e manutenção (O&M) – especialmente a substituição da bateria significa US$60 a 200 num período que pode variar de um a cinco anos – pode constituir um problema financeiro para as famílias rurais de baixa renda.

No *modelo de venda*, o problema do financiamento normalmente é solucionado fornecendo para o comprador um crédito adaptado à sua renda (famílias rurais frequentemente têm uma renda monetária altamente irregular). Muitas vezes, o crédito é oferecido por uma instituição de micro-crédito (rural) e inclui um elemento à fundo perdido (subsídio) para contemplar a capacidade de pagamento do usuário; o SF serve como garantia para o provedor do crédito. Assim, o êxito depende, por uma boa parte, da existência de instituições de micro-crédito. O problema do financiamento do custo irregular de manutenção poderia ser resolvido através de um contrato de serviço. Porém, isso aumenta a carga do custo regular para o usuário e exige bastante planejamento.

No caso do *modelo de* (pagamento para o) *serviço* o consumidor não precisa financiar diretamente o investimento inicial e os custos de O&M. Esta responsabilidade é transferida para a empresa de serviço. Porém, a empresa de fornecimento de energia se autofinancia cobrando uma taxa regular, transferindo assim os custos (incluindo custos de investimento, capital e O&M) para o consumidor. Contrário ao modelo de venda, o usuário não enfrenta o problema do financiamento dos custos iniciais altos ou dos custos irregulares de manutenção. Contudo, como a taxa completa para cobrir os custos totais (US$17/mês no caso da Argentina; SFD com 50 Wp) pode exceder a capacidade de pagamento da população alvo, freqüentemente são aplicados subsídios para alcançar a extensão desejada. Subsídios normalmente são canalizados pelo lado do fornecimento (quer dizer, pelo provedor de serviço) e podem ter a forma de empréstimos com condições favoráveis, subsídios a fundo perdido (para o investimento) ou subsídios cruzados.

Informação e capacitação são importantes especialmente para alcançar uma *manutenção* adequada do SF. Manutenção é muitas vezes um assunto crítico: é necessário para garantir a sustentabilidade técnica do SF, uma pré-condição para a disposição de pagar dos usuários. Junto à qualidade dos componentes e à qualidade do serviço de instalação, a manutenção (e o uso) do sistema determina a sustentabilidade técnica do SF e a vida útil dos componentes. Informação e capacitação para ambos, os usuários e os provedores, são necessárias. Os usuários têm que ser informados sobre as cargas compatíveis com o sistema, os procedimentos necessários de manutenção, como também, os custos relacionados. Os provedores têm que ser treinados para providenciar componentes, instalação e serviços de manutenção de boa qualidade.

Nível macro: A decisão sobre o modelo de gestão no nível micro depende altamente do regulamento no nível macro. Pode-se distinguir duas opções traçadas de políticas de provisão de SFs para o fornecimento de energia no meio rural: a situação do mercado aberto e a situação do mercado regulamentado. A diferença entre estas opções se baseia na profundidade do regulamento considerando as quatro áreas de regulamento relevantes: i) padrões de qualidade, ii) regulamento de preço, iii) metas de extensão, iv) acesso ao mercado. Enquanto a situação do mercado aberto normalmente permite apenas considerar o regulamento dos padrões de qualidade, a situação do mercado regulamentado permite atuar em todas as quatro áreas citadas.

Padrões de qualidade incluem duas áreas: i) normas para os componentes e a instalação do SF e ii) normas para a qualidade do serviço prestado através do SF (p.ex., em relação a interrupções do fornecimento). Padronização objetiva promover a compatibilidade técnica, transparência e proteção do consumidor. Em relação à primeira área existem muitas normas internacionais e propostas para adaptar estes padrões às condições de países em desenvolvimento. Em relação à segunda área, existem poucos exemplos práticos.

Regulamento dos preços de energia é muito comum no setor elétrico. No contexto da eletrificação rural, regulamento de preços é aplicado para manter as tarifas da energia elétrica para as famílias rurais num nível socialmente aceitável e para utilizar subsídios cruzados para compensar as perdas contraídas pela eletrificação *rural* cobrando tarifas dos consumidores *urbanos* que ficam acima do nível de cobertura dos custos. Subsídios cruzados tradicionais exigem uma estrutura de mercado monopolizado.

Definindo **metas de extensão** é uma outra maneira para fomentar o fornecimento de eletricidade em áreas rurais. Metas de extensão são objetivos quantitativos para o fornecimento de energia dentro de um horizonte de tempo definido, que são estabelecidos entre o estado e o provedor de energia. Por isso, precisa-se um contrato de concessão.

O **acesso ao mercado** pode ser ou aberto para todos os potenciais concorrentes ou limitado aos portadoras de uma concessão pública.

A eletrificação rural através de SFs no **âmbito de um mercado aberto** é determinada, principalmente, pelas forças de mercado e a *concorrência no mercado*. Provedores podem escolher os modelos de venda ou de serviço para atender a demanda. O papel do governo é limitado ao de um facilitador que fornece incentivos adequados ao mercado para estimular a disseminação comercial do SF. Por isso, instrumentos de política como financiamento e suporte (informação e capacitação) têm um papel muito mais importante que a intervenção através de regulamentos. O regulamento é limitado à definição e ao cumprimento dos padrões de qualidade.

O objetivo principal no **âmbito de um mercado regulamentado** geralmente não é um desenvolvimento descentralizado do mercado de SFs, mas uma universalização do acesso à energia no nível nacional, baseada em argumentos políticos e de bem-estar. O modelo típico de gestão é o modelo de serviço. O governo outorga concessões exclusivas para distribuidoras de energia existentes ou novas empresas selecionadas pela sua competitividade (*concorrência para o mercado*), autorizando e comprometendo (através de metas de extensão) estas empresas a fornecer serviços de energia (renovável) numa região específica. O governo pode usar medidas de regulamento para influenciar nos preços da eletricidade (e assim, subsídios cruzados) e a qualidade do serviço.

Condições legais, econômicas e políticas para a eletrificação rural através de sistemas fotovoltaicos no Brasil

A partir da metade dos anos 90, o setor elétrico brasileiro foi estruturalmente reformado para introduzir a concorrência, atrair capital privado e gerar rendimentos para o estado. A ampla maioria das distribuidoras, que são os principais agentes responsáveis pela execução da eletrificação rural, foi privatizada. O serviço oferecido pelas portadoras de concessão de distribuição (concessionárias) não atingiu importantes objetivos de política social, como, por exemplo, o aumento substancial dos índices da eletrificação rural, e assim apontou algumas fraquezas do processo de reforma (a taxa nacional da eletrificação rural no Brasil é estimada em 65 % a 75 %, sendo o Norte e o Nordeste as regiões com as taxas mais baixas).

Os principais obstáculos que impediram uma eletrificação mais rápida das áreas rurais foram os fatos i) que somente uma parcela muito pequena dos contratos de concessão das concessionárias privadas continham metas de extensão obrigatórias e ii) que os consumidores foram obrigados a assumir mais que a metade dos custos do investimento relativos a sua ligação.

Estas regras foram alteradas fundamentalmente através da chamada lei de universalização (lei 10.438 do abril de 2002) que compromete todas as concessionárias a abastecer a população da sua área de concessão não ligada à rede sem nenhuma participação dos novos consumidores nos custos de investimento. Numa resolução recente (223/ 2003), a agência reguladora (ANEEL) definiu prazos finais obrigatórios para a ligação em cada área de concessão.

A iniciativa de universalização constitui uma oportunidade para a disseminação de SFs no Brasil no âmbito de um mercado regulamentado. Fora de algumas excessões, até agora as concessionárias não se engajaram na tecnologia fotovoltaica para a eletrificação rural. Uma parte dos potenciais futuros consumidores a serem abastecidos durante o processo de universalização apresentam características que indicam o SF como a tecnologia competitiva para seu serviço. Porém, existem alguns obstáculos importantes que impedem uma aplicação da tecnologia fotovoltaica numa escala maior. O estudo identificou duas áreas principais que precisam de uma regulamentação adicional para realizar os potenciais dos SFs:

A primeira se refere ao financiamento do processo de universalização como um todo no qual a tecnologia fotovoltaica tem que ser integrada. Para cumprir as metas estabelecidas pela ANEEL são necessários investimentos maciços. Até agora, não é claro qual parte dos recursos oriundos do fundo setorial de subsídios (Conta de Desenvolvimento Energético – CDE), citado na lei da universalização para este objetivo, estará acessível como subsídio a fundo perdido para as medidas de universalização. A definição do volume e das condições para o uso deste fundo têm que ser uma prioridade para promover a universalização.

A segunda área se refere especificamente à regulamentação da tecnologia fotovoltaica. Até agora, existe uma incerteza entre as concessionárias se os SFs serão legalmente aceitos como meio para a eletrificação. O primeiro e mais importante assunto que tem que ser definido pela ANEEL é a qualidade de serviço que a concessionária tem que garantir, caso opte pela tecnologia fotovoltaica. Como o SF apresenta características técnicas muito diferentes do abastecimento através da rede (para o qual existem padrões de qualidade), normas específicas de qualidade têm que ser desenvolvidas. O segundo assunto é a definição das tarifas cobradas para o serviço do SF. O cenário mais plausível é que os critérios para o fornecimento através da rede serão estendidos para o SF. Isso implica que a grande maioria dos futuros consumidores rurais se enquadrará na tarifa máxima de baixa renda.

Sustentabilidade técnica e financeira de projetos de sistemas fotovoltaicos domiciliares selecionados no Brasil

O estudo de campo se concentrou em três áreas nos Estados de Alagoas, da Bahia e no Norte de Minas Gerais, pertencendo ao interior semi-árido do Nordeste do Brasil. O interior do Nordeste é a região mais pobre em termos de Índice de Desenvolvimento Humano (IDH) com uma renda per cápita e níveis de alfabetização baixos. A maioria dos usuários entrevistados trabalha em atividades agrícolas em pequenas propriedades (agricultura familiar).

Quatro projetos de SFDs com quatro **modelos de gestão** diferentes foram visitados: i) um modelo de venda (à vista e) à crédito (agente implementador: APAEB), ii) um modelo de aluguel sem compra final (agente implementador: FTV), iii) um modelo de serviço baseado na comunidade (agente implementador: CAR) e iv) um modelo de serviço baseado numa concessionária (agente implementador: CEMIG). O quadro I mostra as características principais dos respectivos modelos de gestão.

Os projetos visitados foram avaliados considerando sua sustentabilidade técnica e financeira. O quadro II sintetiza os resultados para cada projeto (veja em baixo). Antes de apresentar as conclusões a respeito do alcance da sustentabilidade técnica e financeira, são ressaltadas a seguir as **principais conclusões**:

De modo geral, as áreas destinadas a projetos de SFDs muitas vezes se caracterizam por capacidades locais fracas, mercados locais pouco desenvolvidos, baixos níveis de organização política do grupo alvo e difícil acesso. Porém, essas condições variam entre as diferentes áreas. O projeto de APAEB é um exemplo como condições mais favoráveis têm um influência positiva sobre a sustentabilidade. Entretanto, esse caso não deve ser considerado um caso típico senão uma exceção.

Quadro I: Descrição dos projetos de SFDs visitados				
Agente implementador	**APAEB** (Cooperativa rural)	**FTV** (Organização não-governamental)	**CAR** (Empresa de desenvolvimento rural)	**CEMIG** (Concessionária de distribuição de energia elétrica)
Modelo de gestão	Modelo de venda (à vista e) à crédito	Modelo de aluguel sem compra final	Modelo de serviço baseado na comunidade	Modelo de serviço baseado numa concessionária/ situação de mercado regulamentado
Propriedade do SFD	Usuário	Micro-empresário	Associação rural	CEMIG
Financiamento dos custos de investimento via	Fundo rotativo	Doações e créditos subsidiados	Subsídios a fundo perdido	Subsídios a fundo perdido e créditos subsidiados
Responsabilidade para o pagamento do capital investido	Usuário	Micro-empresário	Governo da Bahia	CEMIG, municípios
Prestador do serviço de manutenção	Técnico independente numa base comercial	Não claramente definido (durante o primeiro período a FTV)	Membros da associação especialmente treinados / usuários	Técnicos da CEMIG
Responsabilidade para o pagamento dos custos de O&M	Usuário	Não claramente definido (durante o primeiro período principalmente a FTV)	Usuário através de um fundo de manutenção	Hoje: CEMIG (no futuro: responsabilidade parcial do usuário)
Pagamento mensal regular do usuário (investimento e/ou O&M)	~R$ 18; o preço em R$ depende do preço da carne de bode	R$ 12-14	R$ 9,50 (recomendado); R$ 0-5 (empírico)	Hoje: R$ 0 (no futuro: ~R$ 2 = tarifa baixa renda)
Fonte: Levantamento próprio				

Existe um certo conflito entre maximizar o alcance da extensão (esse é o propósito da iniciativa brasileira de universalização) e alcançar sustentabilidade. As abordagens de CAR e CEMIG focalizam mais o alcance enquanto a filosofia das abordagens de mercado aberto (APAEB, FTV) é mais centrada na sustentabilidade financeira (foi implementada com sucesso no caso de APAEB e sem sucesso no caso de FTV). Os modelos de APAEB e FTV têm em comum que a área do projeto e os usuários são selecionados de acordo com a capacidade (e a disposição) de pagar. Portanto, a compatibilidade desses modelos com o propósito de alcançar um serviço universal é limitada.

Os quatro projetos optaram por modelos de manutenção diferentes. As abordagens de APAEB, CAR e FTV se baseam mais em estruturas de manutenção locais, enquanto a abordagem de CEMIG se baseia num modelo centralizado com técnicos qualificados que se localizam em centros de manutenção regionais. Em áreas com condições locais favoráveis um modelo descentralizado (peso em estruturas locais) parece uma escolha razoável. Em áreas com condições menos favoráveis, uma certa centralização é preferível. Contudo, o que se precisa em qualquer caso é uma articulação ótima da cadeia de manutenção: tarefas básicas devem ser providenciadas por pessoas locais (usuários treinados) e tarefas mais complexas pelos técnicos qualificados localizados nas bases regionais. É essencial estabelecer uma comunicação entre os diferentes elementos da cadeia de manutenção.

A **sustentabilidade técnica** se refere à qualidade do dimensionamento e do equipamento, à qualidade

Quadro II: Avaliação dos projetos de SFDs visitados

Agente implementador	**APAEB** (Cooperativa rural)	**FTV** (Organização não-governamental)	**CAR** (Empresa de desenvolvimento rural)	**CEMIG** (Concessionária de distribuição de energia elétrica)
Sustentabilidade técnica: Pontos fortes (+) e fracos (–)	Regular/ Ruim: Dimensionamento flexível (+); Mercado local para peças de reposição e aparelhos de corrente contínua (+); Qualidade de instalação e componentes (–); Qualidade de manutenção (–)	Ruim: Mercado local para peças de reposição e aparelhos de corrente contínua (+); Qualidade de componentes (–); Dimensionamento (–); Acessibilidade e qualidade de manutenção (–)	Regular/ Ruim: Qualidade de instalação (+); Qualidade de manutenção (–); Acessibilidade de peças de reposição e aparelhos de corrente contínua (–)	Regular/ Bom: Qualidade de instalação (+); Qualidade de manutenção (+); Acessibilidade da manutenção (–); Acessibilidade de peças de reposição e aparelhos de corrente contínua (–)
Sustentabilidade financeira: Pontos fortes (+) e fracos (–)	Regular/ Bom: Arrecadação (+); Capacidade de pagamento (+); Mecanismos de pagamento flexíveis e indexados (+); Sustentabilidade ao longo prazo em risco por causa de diminuição do fundo rotativo (–)	Ruim: Capacidade de pagamento (+) Arrecadação (–); *Comentário: Sustentabilidade financeira ruim é consequência de baixa sustentabilidade técnica e definição insuficiente de responsabilidades de manutenção*	Regular/ Ruim: Contribuição do usuário baixa demais (–); Arrecadação (–); *Comentário: Desempenho depende de condições locais (capacidade de gerenciamento da associação rural, solidariedade, autoridade)*	No momento: Ruim: Não há arrecadação (–); *Comentário: No futuro, a sustentabilidade financeira pode ser alcançada a nível da área total da concessão se os projetos de SFs forem incluídos no esquema setorial de subsídios cruzados*
Articulação com a extensão da rede	Ruim *Comentário: Usuário corre o risco de mal-alocação*	Ruim *Comentário: Micro-empresário corre o risco de mal-alocação*	Ruim *Comentário: Gov. da Bahia corre o risco de mal-alocação*	Bom *Comentário: CEMIG corre o risco de mal-alocação*

Fonte: Levantamento próprio

dos serviços de instalação e à qualidade e à acessibilidade de serviços de manutenção e peças de reposição. O estudo chegou aos seguintes resultados:

- Em todos os projetos visitados os reatores apresentaram altas taxas de falhas. Isso exige uma atuação das instituições responsáveis na área de gestão de qualidade, padronização e metrologia.

- Um ponto crítico para alcançar um funcionamento técnico satisfatório é a informação e o treinamento adequados do usuário. O treinamente deve conter informações sobre a capacidade limitada do SFD, as cargas compatíveis, o tratamento da bateria e do controlador de carga, as atividades preventivas de manutenção, como se comunicar com o técnico responsável para as tarefas de manutenção mais sofisticadas e a divisão de responsabilidades de manutenção. O treinamento deve ser adaptado ao nível educacional dos usuários e repetido de vez em quando.

- A gestão local da manutenção (diagnóstico de uma falha, informação sobre onde conseguir peças de reposição e serviço de manutenção, gestão de despesas de manutenção) exige capacidades de gerenciamento que, normalmente, não se encontram facilmente em áreas rurais.

- A qualidade dos serviços de manutenção (e instalação) depende do treinamento dos técnicos responsáveis. Pode ser percebida uma contradição entre a acessibilidade e a qualidade dos serviços de manutenção relacionada à saída de pessoas qualificadas do campo (*brain-drain*), um fenômeno comum em áreas rurais estruturalmente fracas. Manutenção local é facilmente acessível, mas de baixa qualidade. Manutenção centralizada tem uma boa qualidade, mas é menos acessível e mais cara.

- A sustentabilidade técnica aumenta através do desenvolvimento de mercados locais de peças de reposição e de aparelhos de corrente contínua. Isso exige uma concentração relativamente alta de SFDs.

- Normas flexíveis para o dimensionamento e o projeto do sistema adaptadas à demanda do usuário aumentam a satisfação e evitam alterações do sistema pelo próprio usuário que causem problemas técnicos.

A **sustentabilidade financeira** é determinada, por um lado, pelo volume dos custos de investimento, capital e O&M a serem cobertos (isso determina o fluxo de caixa que tem que ser gerado) e, por outro lado, pela capacidade e a disposição de pagar dos usuários, como também, o cumprimento dos pagamentos (estes fatores determinam se o fluxo de caixa necessário pode ser arrecadado). Em seguida, são ressaltadas as conclusões principais:

Os *custo*s repassados para o consumidor têm que ser minimizados para contemplar a baixa capacidade de pagamento. Existem pelo menos duas estratégias gerais para conseguir isso:

- Os custos podem ser reduzidos economizando na qualidade do serviço (p.ex., manutenção). O problema é que a sustentabilidade técnica pode não ser alcançada e, assim, a sustentabilidade financeira também não será alcançada ao longo prazo.

- Os custos podem ser reduzidos evitando abastecer áreas caracterizadas por longas distâncias do centro urbano próximo, difícil acesso, níveis baixos de educação e desenvolvimento fraco de mercados locais, todos fatores que aumentam os custos. O problema é que o alcance da extensão será limitado.

Há três estratégias para tratar com um determinado nível médio baixo da *capacidade de pagamento*:

- A primeira estratégia é selecionar áreas com uma capacidade suficientemente alta de pagamento. Porém, isso implica que o alcance da extensão será limitado.

- A segunda estratégia é adaptar as modalidades de pagamento à renda dos consumidores. Exemplos indexam o pagamento com um produto agrícola localmente produzido, permitem prazos maiores que o pagamento mensal e criam um fundo de manutenção.

- A terceira estratégia é usar subsídios a fim de substituir a falta de capacidade de pagamento. Uma exigência comum considerando a proporção dos subsídios é que pelo menos os custos de O&M devem ser assumidos pelos usuários, para alcançar a auto-suficiência do projeto. Esta exigência pode ser difícil de ser atendida, pois as primeiras estimativas indicam que os custos mensais de O&M podem alcançar valores de R$ 17 a 21. Níveis superiores de subsídios podem ser alcançados se os projetos com SFDs forem incluídos no esquema de subsídios cruzados do setor elétrico brasileiro e se o critério de sustentabilidade financeira usado pela ANEEL (equilíbrio econômico-financeiro) for observado.

A *disposição de pagar* depende i) do benefício do SFD percebido, quer dizer, da confiabilidade técnica, ii) da transparência das informações sobre as características técnicas do SFD e os custos relacionados, iii) da acessibilidade local e dos custos relativos de um serviço alternativo de eletricidade. Uma sustentabilidade técnica baixa, informações enganosas sobre as características do sistema e os custos, como também, a acessibilidade de eletricidade da rede diminuem a disposição de pagar dos usuários.

Em relação ao *cumprimento dos pagamentos*, os seguintes resultados são ressaltados:

- É essencial que as relações de propriedade e as responsabilidades para assumir os custos do crédito, do aluguel e da manutenção sejam claramente especificadas e formalizadas num contrato. Pagamentos têm que ser formalizados através da emissão de recibos ou faturas.

- A legitimidade percebida e a autoridade da coordenação local do projeto é essencial para fazer respeitar os pagamentos. Isso é importante porque recorrer à insituição judicial mais próxima implica assumir custos altos e, portanto, muitas vezes não é uma alternativa viável para solucionar controvérsias. Nas abordagens baseadas na comunidade, legitimidade e autoridade dependem muitas vezes de uma pessoa só (normalmente uma pessoa com características de liderança). Se esta pessoa sai da área do projeto, não somente o cumprimento dos pagamentos, mas a continuidade de toda a gestão local do projeto estará comprometida.

Os impactos dos SFs no desenvolvimento rural

Podem ser distinguidos dois principais efeitos de serviços de fornecimento de energia no desenvolvimento rural: o efeito direto nas necessidades e atividades básicas (água potável garantida, iluminação e preparo de comida de boa qualidade e saudável, etc.) e o efeito indireto na geração de renda e no emprego (através de uso de motores, etc., para atividades produtivas).

A implementação mais comum da tecnologia fotovoltaica para o fornecimento de energia no meio rural são os SFDs. Como os SFDs não estão aptos para a operação de aparelhos que exigem uma carga maior (p.ex., máquinas de costura elétricas), seus benefícios potenciais resultam principalmente do efeito direto. Outras aplicações importantes da tecnologia fotovoltaica são SFs (maiores) para escolas, postos de saúde, centros comunitários, sistemas de bombeamento de água para irrigação, abastecimento de água para animais e homens, tanto como, SFs para cercas elétricas.

Os seguintes resultados são baseados na pesquisa sobre SFDs e SFs para escolas e centros comunitários. SFs projetados explicitamente para o uso produtivo (como cercas elétricas e irrigação) não foram considerados:

Qualidade de vida: Usuários de SFDs, em geral, apreciam muito seu SFD, principalmente por causa do aumento de sua qualidade de vida. O acesso fácil à iluminação em qualquer momento atenua substancialmente o fardo quotidiano e realça qualquer tipo de atividade doméstica. Como a luz elétrica substitui a queima de querosene ou óleo diesel para a iluminação dentro da casa, o SFD melhora a situação sanitária e de saúde da família consideravelmente. A ampla maioria dos usuários aprecia seu rádio e TV por causa da possibilidade de obter informação e das oportunidades de entretenimento. Normalmente, as mulheres e as crianças aproveitam mais do SFD, pois permanecem relativamente mais tempo em casa.

Educação: Iluminação através do *SFD* permite às crianças e aos adultos a estudar durante à noite na sua casa com iluminação constante de alta qualidade. Entretanto, estudar não é uma atividade comum nas horas da noite. *SFs para escolas e centros comunitários* são um meio para aumentar a quantidade e a qualidade do ensino nas escolas rurais. Iluminação de boa qualidade melhora o ensino à noite para alfabetização de adultos, e a possibilidade de utilizar fitas de vídeo, TV e computadores amplia em geral a oportunidade de ação para o ensino. Porém, estas novas oportunidades são freqüentemente desperdiçadas devido a problemas de articulação entre o Ministério de Minas e Energia (MME), que coordena um programa para equipar escolas de SFs (Prodeem) e o Ministério de Educação (MEC) e os municípios que têm que fornecer os recursos financeiros para professores e aparelhos elétricos.

Geração de renda: As entrevistas indicam que, exceto algumas poucas exceções, o uso de SFDs não contribuiu para o aumento da renda familiar através do estimulo a atividades de geração de renda (p.ex., atividades artesanais à noite). Dois fatores são importantes para promover novas atividades de geração de renda: i) uma política integrada de desenvolvimento rural, incluindo a promoção de capacidades locais de gerenciamento, acesso ao mercado, educação e serviços de infra-estrutura básica, além da energia elétrica; ii) geralmente um volume maior de energia elétrica do que fornecido por um SFD típico.

Recomendações

O **primeiro item** a ser discutido é se a promoção de projetos de SFs para a eletrificação rural deve ser uma área prioritária da cooperação para o desenvolvimento:

Em geral, são apresentados dois argumentos principais em favor da promoção de projetos de SFs. Primeiro, sua contribuição para a proteção do clima global; segundo, sua contribuição para a redução da pobreza através do estímulo ao desenvolvimento econômico e social em áreas rurais.

A proteção do clima não pode ser o argumento principal para promover SFs, pois a sua contribuição à redução de emissões globais de gás causador do efeito estufa é relativamente pequena (SFs são apropriados para áreas rurais de pouca densidade habitacional e baixa demanda de energia elétrica). Além disso, os custos da redução de emissões são relativamente altos em comparação com outras tecnologias para a geração de energia renovável, por exemplo, energia eólica ou mini centrais hidrelétricas.

No que se refere à contribuição para a redução da pobreza, o estudo empírico mostrou, que SFDs e SFs para escolas e centros comunitários contribuem com êxito para melhorar a qualidade das condições de vida e de saúde dos beneficiários. Em relação à dimensão econômica da pobreza, os sistemas, em geral, não estimularam atividades de geração de renda.

Além disso, o fornecimento de uma tecnologia nova e relativamente cara para uma população rural com poder aquisitivo e nível educacional baixos freqüentemente enfrenta problemas consideráveis. As barreiras específicas em regiões estruturalmente fracas dificultam a garantia da sustentabilidade técnica e financeira de projetos de SFs ao longo prazo e muitas vezes implicam a necessidade de subsidiar uma proporção substancial dos custos.

Todos estes argumentos pleiteam a posição que a promoção da tecnologia fotovoltaica para a eletrificação rural não deve ser uma área prioritária da cooperação alemã para o desenvolvimento. Todavia, em nichos determinidos SFs podem ser uma alternativa racional do ponto de vista econômico e ecológico para eletrificar moradores rurais pobres que melhora consideravelmente as condições básicas de vida. Porém, para alcançar impactos mais amplos no desenvolvimento local (geração de renda, participação política) SFs devem ser integrados como um elemento numa estratégia mais ampla de desenvolvimento rural para a redução da pobreza.

O **segundo item** a ser tratado é se os SFs são promovidos para a eletrificação rural, o que deve ser feito?

Se a decisão para promover projetos de SFs for tomada, a cooperação para o desenvolvimento deve se concentrar nas três linhas de ação seguintes: i) desenvolver um regulamento adequado para a eletrificação rural através de SFs; ii) desenvolver e implementar modelos de gestão sustentáveis para SFs adaptados ao contexto regional; iii) integrar projetos de SFs numa estratégia mais ampla de desenvolvimento rural a fim de maximizar os impactos no desenvolvimento.

Regulamento: As medidas no âmbito do regulamento têm que objetivar a eliminação de barreiras institucionais, políticas e econômicas existentes para projetos de eletrificação rural através de SFs. Para isso, é especialmente importante criar um campo de ação equilibrado com regras iguais de jogo para a tecnologia fotovoltaica no setor elétrico.

Modelos de gestão sustentáveis: Não existe um único modelo de gestão ótimo, porque cada modelo tem que ser adaptado às condições políticas, sociais e econômicas reais da região e às características da organização executora. Porém, os seguintes pontos-chave devem ser observados:

- Articulação do projeto com a situação do setor (observar planos de extensão da rede e tendências de preços da eletricidade da rede) e uso do SF como tecnologia de menor custo;

- Integração e promoção de estruturas locais (capacitação dos usuários, contar com as organizações locais existentes para a coordenação e administração dos serviços de manutenção, desenvolvimento de mercados locais para peças de reposição e aparelhos);

- Formalização de modelos de gestão, controle de qualidade e aprendizagem organizacional (contratos formais e recibos para o pagamento, padronização de componentes e monitoramento da instalação).

Nas circunstâncias especiais do **Brasil,** devido ao processo de universalização em andamento e ao regulamento atual, o *modelo de serviço através de concessionárias* parece ser a abordagem mais adequada, porque isso pode garantir o acesso aos recursos financeiros necessários, leva à articulação com a extensão da rede e assegura o uso do SF como tecnologia de menor custo. Esta abordagem pode integrar organizações existentes com experiência na gestão local de projetos de SFs como prestadoras de serviço representantes (sub-contratadas) da concessionária. A sustentabilidade financeira a nível da área de concessão deve ser alcançada através do critério do equilíbrio econômico-financeiro considerado pela agência reguladora ANEEL quando estabelece o nível das tarifas.

Entretanto, se as incertezas relacionadas à regulamentação do financiamento da universalização e às exigências de qualidade para SFs não forem superadas, as concessionárias brasileiras não se engajarão numa escala maior em projetos de SFs. Além disso, resistência contra e falta de experiência com projetos de SFs entre as concessionárias têm que ser resolvidas. Adicionalmente, uma atenção especial deve ser dedicada à integração e promoção de estruturas locais, pois as concessionárias normalmente não têm uma base local em áreas distantes.

Estratégia de desenvolvimento rural: Projetos de SFs bem adaptados e gerenciados, em geral, não são suficientes para alcançar impactos econômicos significantes no desenvolvimento rural. Experiências mostram que o fornecimento de eletricidade em regiões estruturalmente fracas não leva automaticamente ao efeito catalisador desejado no desenvolvimento regional. Para estimular um desenvolvimento rural amplo são necessárias abordagens articuladas e descentralizadas abertas para a solução tecnológica de fornecimento de energia a ser aplicada (opções: SFDs, SFs para o uso comunitário *e* produtivo, mini centrais hidrelétricas, energia da biomassa, extensão da rede, etc.) contendo vários campos de ação (infra-estrutura, instituições, educação e treinamento, acesso ao mercado, etc.). Assim, esforços são necessários para desenvolver e implementar estratégias integradas para o desenvolvimento rural nas quais SFs devem ser um elemento.

Executive Summary

Environmental and climate protection as well as the related need to implement sustainable energy supply systems are issues of great importance in current development cooperation. Another central challenge for development cooperation is to provide basic infrastructure for the poor. The lack of basic infrastructure services is especially pronounced in rural areas, where the vast majority of the world's poor live. Thanks to technological progress, renewable energy technologies (RET) are an increasingly attractive solution for rural electricity supply. This is especially true for solar photovoltaic technology, which has recently been used more and more in so-called off-grid photovoltaic systems (PVS) to supply sparsely populated areas with no access to the national grid.

The attractiveness of using PVS for rural energy supply is rooted in the possibility to take advantage of a potential win-win situation: on the one hand, rural development can be enhanced by supplying a wider range of the rural population with electricity in an economically viable manner and on the other hand this makes it possible to avoid harmful ecological effects that would result if conventional technologies were used. Nevertheless, experiences from different developing countries indicate that several electrification projects with PV technology have failed to achieve technical and financial sustainability and that the potential benefits have not been realized in a satisfactory manner.

The present investigation is intended to provide an orientation for development cooperation as regards best practices to promote sustainable electricity supply with PVS, based on a case study for Brazil. Three central problem dimensions were analyzed in order to assess the sustainability and the benefits of PVS projects: i) the sectoral (legal, economic and political) conditions for rural electrification with PVS (macro-level); ii) the demands on project management, i.e. in terms of organizational and financing issues, if technical and financial sustainability is to be achieved (micro-level); iii) the impacts of PVS projects on rural development.

Context for the Use of Photovoltaic Systems for Rural Electrification in Developing Countries

Technical options: There are two principal technical alternatives for electricity supply to rural areas: the first is extension of the national grid; the second is autonomous off-grid electricity generation. Recently, RET have been used more and more for off-grid electricity generation, competing with off-grid diesel generation and grid extension. The relative competitiveness situation of the different technologies for rural electricity supply depends on the one hand on local climatic and geographic conditions (this is especially true for RET) and on the other hand on the electricity consumption density (kWh/km^2/month) of the area to be supplied. PVS are competitive in areas with very low consumption densities (i.e. sparsely populated areas with low electricity consumption per household). Still, as a general rule the average cost for electricity supply increases with declining consumption density, as economies of scale vanish. What this means is: the lower the consumption density, the higher the average cost.

Socioeconomic characteristics of demand: The target regions that are suited for electrification with PVS in developing countries, i.e. regions with low consumption density, usually have high shares of low-income households and households with low educational levels. This implies on the one hand that household ability to pay is commonly too low to cover the full costs of any (even least-cost) supply technology, and this in turn means that demand cannot be met in a market setting. This situation can be considered a case of market failure and justifies the use of subsidies to reach the rural poor with electricity services, unless it is regarded as sufficient to supply only relatively wealthy rural households. The second implication of the conditions in the target regions is that, given their low educational levels, substantial capacity-building efforts have to be undertaken in introducing PV technology to these areas in order to assure adequate maintenance. Still, the socioeconomic characteristics of demand may vary considerably between different regions and countries.

Institutional and informational barriers: PVS face a series of institutional and informational barriers that are typical for the introduction of a new technology. There is a lack of information among the rural population, potential service providers, and politicians about the potentials of PV technology. This, together with a lack of experience with the management and maintenance of PVS projects, often leads to the exclusion of PV technology from official electrification programs. In addition, in many developing countries there is lack of quality standards for national PVS components, which leads to unreliable product quality.

Structure of the electricity sector: The electricity industry has traditionally been composed of state-owned, monopolistic utilities. Poor performance of this organizational model in developing countries in terms of service quality and coverage as well as budgetary concerns resulting from a lack of financial sustainability have given rise to comprehensive reform efforts, which are being supported by international donors. These reforms aim at privatizing and liberalizing former state-run utilities and are leading toward a market-based approach. This new organizational model reshapes the conditions for the entire sector's performance. Partnerships with private agents provide new options but also considerable challenges for rural electrification programs. On the one hand, attracting private capital and know-how broadens the scope for decentralized approaches using RET such as PVS. On the other hand, profitability of rural electrification is unlikely to be achieved, and thus efficient subsidy and incentive mechanisms have to be devised if the disadvantaged population is to be served.

Approaches to Rural Electrification with Photovoltaic Systems

To encourage an electricity supplier to include PVS in its range of services and to direct them to a population traditionally excluded from access to the grid, the following elements must be in place: i) an adequate delivery model, including sustainable financing mechanisms as well as information and capacity-building measures (micro-level); ii) a regulatory framework adapted to the needs of PVS (macro-level).

Micro-level: At the micro-level an electricity supplier has to decide which delivery model will be most adequate to serve a rural area with off-grid PVS, given the regulatory framework in place (see below). There are two main options: i) the sales model and ii) the service model. Related to this, iii) sustainable financing mechanisms as well as iv) adequate information and capacity-building measures have to be provided for.

Under the **sales model**, the PVS *equipment* is sold and there is a property transfer from the seller to the buyer. The sales model may be broken down into three subtypes: the cash sales model, the credit sales model, and the leasing model with ultimate purchase. The common elements are that the user becomes the owner of the system and that the sales contract does not include maintenance service (although the components of the PVS may be covered by a manufacturer's guarantee). This means that maintenance and replacement of components (especially the battery) have to be provided for by the buyer himself, unless he agrees on an additional maintenance contract with a service provider.

Under the **service model**, the electricity *service* is sold and the PVS equipment remains the property of the supplier. The service model may be broken down into two subtypes: the fee-for-service model (commonly referred to simply as the 'service model') and the leasing model without ultimate purchase. The common element is that the supplier remains the owner of the PVS. The distinguishing element is that the fee-for-service model includes rental of the equipment as well as a maintenance service, whereas the leasing model without ultimate purchase includes only rental of the PVS, and the maintenance service has to be provided for separately by the user.

Financing mechanisms play a crucial role, since the target population is typically unable to cover the considerable investment costs out of pocket (a residential PVS, a so-called solar home system – SHS – with a capacity of 50 Wp costs between

500 and 1,000 US$), and usually has no easy access to credit. Also, the operation & maintenance (O&M) costs (especially battery replacement: 60 to 200 US$ every one to five years) constitute a financing problem for low-income rural households.

Under the *sales model* the financing problem is usually tackled by providing a credit to the buyer which is adapted to his income situation (rural households often have highly irregular monetary incomes). Often this credit is offered by a (rural) micro-finance institution and includes a grant element (subsidy) adapted to the low user ability to pay; the PVS then serves as security for the lender. Thus success depends to a good extent on the existence of micro-finance institutions. The problem of financing the irregular maintenance costs could be solved on the basis of service contracts. However, this increases the regular user cost burden and requires considerable awareness and foresight.

Under the (fee-for-) *service model* the consumer does not have to directly finance the initial investment and O&M costs. This responsibility is transferred to the service company. However, the energy service company typically refinances itself by charging a regular fee, passing the costs (including investment, capital, and O&M costs) on to the consumer. In contrast to the sales model, here the user is not faced with the problem of having to finance either the high initial costs or the irregular maintenance costs. Still, since a full cost-recovering fee (17 US$/month for the Argentine case; SHS with 50 Wp) may exceed the ability to pay of the target population, subsidies are often used to achieve the desired outreach. Subsidies are usually channeled through the supply side (i.e. the service provider) and can take the form of soft loans, (investment) grants, or cross-subsidies.

Information and capacity-building measures are especially important to achieve an adequate *maintenance* of the PVS. Maintenance often is a critical issue: it is necessary to ensure the technical sustainability of the PVS, a precondition for user willingness to pay. Together with component quality and the quality of installation service, the maintenance (and use) of the system determines the technical sustainability of the PVS and the lifespan of its components. Information and capacity-building are necessary for both users and suppliers. Users have to be informed about what loads are compatible with the system, on necessary maintenance procedures, as well as about related costs. Suppliers have to be trained to provide good quality components and installation and maintenance services.

Macro-level: The decision on a delivery model at the micro-level is highly dependent on the regulatory framework in place at the macro-level. Two stylized policy options for the provision of PVS for rural energy supply can be distinguished: the open-market framework and the regulated-market framework. The difference between these options is rooted in regulatory depth as regards the four relevant regulatory areas: i) quality standards, ii) price regulation, iii) outreach targets, iv) market entry. Whereas the open-market framework usually allows only for regulatory action concerning quality standards, the regulated-market framework allows for action in all four regulatory areas.

Quality standards comprise two areas: i) standards for PVS components and PVS installation and ii) standards for the quality of service provided by PVS (e.g. as regards supply interruptions). Standardization aims at promoting technical compatibility, transparency, and consumer protection. As regards the first area, there are many international standards and proposals available to adapt these standards to the conditions of developing countries. As regards the second area, examples from practice are very rare.

Price regulation is very common in the electricity sector. In the context of rural electrification, price regulation is used to maintain the electricity tariff for rural households at a socially acceptable level; it also uses cross-subsidies to compensate for losses incurred in *rural* electrification by charging *urban* customers a tariff that lies above the level of cost coverage. Traditional cross-subsidies require a monopolistic market structure.

Setting **outreach targets** is another way to foster electricity supply in rural areas. Outreach targets are quantitative targets for the provision of energy within a defined time frame; these are agreed upon between the state and an energy provider. They thus require a concession contract.

Market entry can either be open to all potential competitors or limited to holders of a public concession.

Rural electrification with PVS in an **open-market framework** is mainly determined by market forces and *competition in the market*. Providers may choose the sales or the service model to meet demand. The role of the government is limited to that of a facilitator who provides market-compatible incentives in order to stimulate the commercial dissemination of PVS. Thus policy instruments like financing and supporting measures (information and capacity-building) play a much more important role here than regulation-based intervention. Regulation is limited to the definition and enforcement of quality standards.

The main objective under a **regulated-market framework** is usually not development of a decentralized market for PVS but a countrywide universalization of access to energy based on political and welfare aspects. The typical delivery model is the service model. The government grants exclusive concessions to existing energy utilities or new competitively selected firms (*competition for the market*), which authorize and oblige (via outreach targets) these companies to provide (renewable) energy services in a specific region. The government can use regulatory measures to influence both electricity prices (and thus cross-subsidies) and the quality of the service.

Legal, Economic, and Political Conditions for Rural Electrification with Photovoltaic Systems in Brazil

Starting in the mid-1990s, the Brazilian electricity sector was structurally reformed with an eye to introducing competition, attracting private capital, and generating public-sector revenues. The vast majority of the distribution companies, the main agents responsible for carrying out rural electrification, were privatized. The service provided by the holders of distribution concessions (concessionaires) failed to meet important social-policy objectives, e.g. accelerating rural electrification indices, and thus pointed to some drawbacks of the reform process (estimations for the national Brazilian rural electrification rate vary between 65 % and 75 %, with the lowest rates being recorded for the North and the Northeast).

The main obstacles impeding a more rapid electrification of rural areas were the facts i) that only a very small fraction of the concession contracts of privatized concessionaires contained binding outreach targets and ii) the consumers were obliged to cover far over half of the investment costs related to their service connection.

These rules have been fundamentally altered by the so-called universalization law (Law 10.438 of April 2002), which obliges all concessionaires to supply the unconnected population in their concession areas without any charges for the new customers toward the investment costs. In a recent resolution (223/2003) the regulatory agency (ANEEL) has defined binding connection deadlines for every concession area.

The universalization initiative constitutes an opportunity for the dissemination of PVS in Brazil within a regulated-market framework. Apart from some exceptions, concessionaires have until now made no use of PV technology for rural electrification. A fraction of the potential future consumers to be supplied during the universalization process displays characteristics which would indicate PVS as a competitive instrument for providing them with electricity. However, there are some important obstacles that work counter to a use of PV technology on a larger scale. The study identified two main areas that need further regulation in order to realize the potentials of PVS:

The first relates to the financing of the universalization process as a whole, in which PV technology has to be integrated. In order to fulfill the targets set by ANEEL, massive investments have to be made. Until now it is not clear what share of the resources of the sectoral subsidy fund (CDE) allocated in the universalization law for this purpose is going to be available as grants for universalization measures. Definition of amounts and conditions for the use of these funds has to be a priority if universalization is to be furthered.

The second area relates specifically to the regulation of PV technology. At present there is uncertainty among the concessionaires as to whether PVS will be legally accepted as a means of electrification. The first and most important issue that has to be addressed by ANEEL is the service quality that a concessionaire has to guarantee if he opts for PV technology. Since PVS have technical characteristics that are very different from grid supply (for which reliable quality standards exist), specific quality standards have to be developed. The second issue that has to be addressed is the tariff to be charged for PVS service. The most probable scenario here would be extension to PVS of the criteria used for grid supply. This implies that the vast majority of future rural consumers will qualify for the maximum low-income tariff (*baixa renda*).

Technical and Financial Sustainability of Selected Solar Home System Projects in Brazil

The field study focused on three rural areas in the states of Alagoas, Bahia, and (northern) Minas Gerais, which are part of the semi-arid hinterland of Northeast Brazil. The hinterland of the Northeast is the poorest Brazilian region as defined by HDI, with low per capita incomes and low alphabetization levels. The majority of the users interviewed engaged in small farming activities.

Four SHS projects with four different **delivery models** were visited: i) a (cash and) credit sales model (implementing agent: APAEB), ii) a leasing model without ultimate purchase (implementing agent: FTV), iii) a community-based service model (implementing agent: CAR), and iv) a utility-based service model (implementing agent: CEMIG). The following Table III shows the characteristics of the respective delivery models in more detail.

The projects visited were assessed as regards their technical and financial sustainability. The results for the respective projects are presented in Table IV (see below). Before presenting the conclusions on the achievement of technical and financial sustainability, the study highlights the following **central observations**:

- Generally speaking, target regions for SHS projects are often characterized by weak local capacities, poor development of local markets, a low degree of target-group political organization, and difficult access. Nevertheless, these conditions vary across project regions. The APAEB project is one example for how more favorable conditions may have positive effects on project performance. However, it should be considered not as a typical case but more as a exception.

- There is a certain trade-off between maximizing outreach (as intended by the Brazilian universalization initiative) and reaching sustainability. While the CAR and the CEMIG approaches focus more on outreach, the philosophy of the open-market approaches of APAEB and FTV is centered more on financial sustainability (with implementation relatively successful in the case of APAEB and unsuccessful in the case of FTV). A common characteristic of the APAEB and the FTV models is that project areas and users are selected according to their ability (and willingness) to pay. They are therefore not wholly compatible with the goal of universal service coverage.

- The four projects have opted for different maintenance models. While the APAEB, the CAR, and the FTV approaches rely more on local maintenance capacities, the CEMIG approach relies on a centralized model, with qualified technicians located at regional maintenance centers. In areas

Table III: Description of the SHS Projects Visited

Implementing agent	**APAEB** (Rural cooperative)	**FTV** (Nongovernmental organization)	**CAR** (Rural development company)	**CEMIG** (Utility/ distribution concession holder)
Delivery model	(Cash &) credit sales model	Leasing without ultimate purchase	Community-based service model	Utility-based service model/ regulated-market framework
Property of SHS	User	Micro-entrepreneur	Rural association	CEMIG
Financing of investment costs via	Revolving fund	Donations and subsidized credits	Grants	Grants & subsidized credits
Responsibility for repayment of investment capital	User	Micro-entrepreneur	Government of Bahia	CEMIG, municipalities
Maintenance service provider	Independent technician, on a commercial basis	Not clearly defined (during first period, FTV)	Specially trained association members/ users	CEMIG technicians
Responsibility for payment of O&M costs	User	Not clearly defined (during first period, mainly FTV)	User via maintenance fund	Today: CEMIG (future: partial responsibility of user)
Regular monthly user payment (investment and/or O&M)	~R$ 18; price in R$ pegged to price of goat meat (index)	R$ 12-14	R$ 9.50 (recommended); R$ 0-5 (empirical)	Today: R$ 0 (future: ~R$ 2 = regulated tariff for low-income rural households)

Source: Own compilation

with favorable conditions relying primarily on local maintenance capacities seems to be a reasonable choice. In areas with less favorable conditions some centralization of maintenance services seems to be preferable. However, what is needed in any case is an optimal articulation of the maintenance chain, with basic maintenance tasks provided locally and more complex maintenance tasks provided by trained technicians located at regional centers. It is essential to establish reliable communications between the links of the maintenance chain.

Technical sustainability relates to the quality of dimensioning and system design, the quality of installation services, and the quality and availability of maintenance services and spare parts. The study came up with the following results:

- In all projects visited the electronic ballast showed high failure rates. This calls for action on the part of the responsible institutions in the field of quality management, standardization, and metrology.
- Adequate user information and training is a critical point in achieving satisfactory technical operation. The training should include information about the limited capacity of the SHS, compatible loads, handling of battery and charge controller, preventive maintenance activities, means of communication with the technician responsible for more sophisticated maintenance tasks, division of maintenance re-

Table IV: Assessment of the SHS Projects Visited

Implementing agent	APAEB (Rural cooperative)	FTV (Nongovernmental organization)	CAR (Rural development company)	CEMIG (Utility/ distribution concession holder)
Technical sustainability: strengths (+) and weaknesses (–)	Regular/ Bad: Flexible dimensioning (+); local market for spare parts and DC appliances (+); quality of installation and components (–); quality of maintenance (–)	Bad: Local market for spare parts and DC appliances (+); quality of components (–); dimensioning (–); availability and quality of maintenance (–)	Regular/ Bad: Quality of installation (+); quality of maintenance (–); availability of spare parts and DC appliances (–)	Regular/ Good: Quality of installation (+); quality of maintenance (+); availability of maintenance (–); availability of spare parts and DC appliances (–)
Financial sustainability: strengths (+) and weaknesses (–)	Regular/ Good: Fee collection (+); ability to pay (+); flexible and indexed payment mechanism (+); long term sustainability at risk because of shrinking revolving fund (–)	Bad: Ability to pay (+); fee collection (–); *Comment: Bad financial sustainability is a consequence of poor technical sustainability and poorly defined maintenance responsibilities*	Regular/ Bad: User contributions too low (–); fee collection (–); *Comment: Performance depends on local conditions (management capacity of rural associations, solidarity, authority)*	At present: Bad: No fees collected (–); *Comment: In the future financial sustainability can be achieved on the scale of the overall concession area if PVS projects are included in the sectoral cross-subsidy scheme*
Coordination with grid extension	Bad *Comment: User bears risk of misallocation*	Bad *Comment: Micro-entrepreneur bears risk of misallocation*	Bad *Comment: Gov. of Bahia bears risk of misallocation*	Good *Comment: CEMIG bears risk of misallocation*

Source: Own compilation

sponsibilities. The training should be adapted to the educational level of the users and be repeated from time to time.

- Local management of maintenance (failure diagnosis, information about where to get spare parts and maintenance service, administration of maintenance expenditures) requires management capacities that typically are not well developed in rural areas.

- The quality of maintenance (and installation) services depends on the training of the technicians in charge of it. There is a trade-off involved between the availability and the quality of maintenance services; this is related to the "brain-drain" phenomenon affecting structurally weak rural areas: typically, local maintenance is readily available but of low quality. Centralized maintenance is of good quality but less available and more expensive.

- Technical sustainability is enhanced by the development of local markets for spare parts and DC appliances. This calls for a relatively high concentration of SHS.

- Flexible norms for system dimensioning and design that are adapted to user needs raise user satisfaction and prevent home-made system alterations which may cause technical problems.

Financial sustainability is determined on the one hand by the amount of investment, capital, and

O&M costs to be covered (this determines the cash flow that has to be generated) and on the other hand by user ability to pay and willingness to pay as well as by the possibility of enforcing payment (these factors determine whether the cash flow necessary can in fact be collected). In what follows, the main conclusions are highlighted:

Costs passed on to the consumers have to be minimized in order to accommodate their relatively low ability to pay. There are at least two general strategies to achieve this:

- Costs can be reduced by economizing on the quality of service (e.g. maintenance). The trade-off is that technical sustainability may not be achieved and thus financial sustainability may not be reached in the long run.

- Costs can be reduced by not supplying areas far removed from the closest urban center, difficult to access, and marked by low educational levels and poor development of local markets; all of these are factors that raise transaction costs. The trade-off is that outreach will be limited.

There are three strategies to deal with a given low average *ability to pay*:

- The first strategy is to select areas with a sufficiently high ability to pay (e.g. APAEB, FTV). However, this implies that outreach will be limited.

- The second strategy is to adapt the payment modalities to the income situation of the consumers. Examples would be an indexing of payments to an agricultural product that is locally produced (e.g. APAEB), allowance for longer than monthly payment intervals (e.g. APAEB), and setting up of a maintenance fund (e.g. CAR).

- The third strategy is to use subsidies to substitute for the lack of ability to pay (all projects visited used some kind of subsidies, though to different degrees). A common requirement regarding the share of subsidies is that at least the O&M costs should be covered by users in order to achieve project self-sufficiency. This requirement could prove hard to meet in the Brazilian context: preliminary estimates indicate that monthly O&M costs can be as high as 17 to 21 R$. Higher subsidy levels can be achieved by integrating PVS activities into the cross-subsidy scheme of the regulated-market framework of the Brazilian electricity sector and by applying the financial sustainability criterion of the regulatory agency ANEEL (*equilibrio econômico-financeiro*).

Willingness to pay depends on i) the perceived benefit of the SHS, i.e. on its technical reliability, ii) the transparency of information about the technical features of the SHS and the related costs, iii) the local availability and the relative costs of an alternative electricity service. Low technical sustainability, misleading information about system characteristics and costs, as well as availability of grid electricity lower user willingness to pay.

Regarding the *enforceability of payments*, the study came up with the following conclusions:

- It is essential that the question of ownership and the responsibilities involved in bearing credit, leasing, and maintenance costs are clearly specified and formalized in a contract. Payments have to be formalized by issuing receipts or bills.

- The perceived legitimacy and authority of local project management are essential to enforcing payments. This is especially important because recourse to the closest judicial institution involves high costs and thus often is not a practicable alternative for settlement of disputes. In community-based approaches legitimacy and authority often depend on one single person (typically a person with leadership functions). If this person leaves the project area, not only the enforceability of payments but the continuity of the overall local project management may be endangered.

Rural Development Impacts of Photovoltaic Systems

It is possible to distinguish two main effects of energy services on rural development: a direct effect on basic needs and activities (safe drinking water, good quality and healthy lighting, cooking, etc.) and an indirect effect on income generation and employment (the use of motors etc. for productive activities).

The most common means of implementation of PV technology for rural energy supply are SHS. Since SHS are not suited for the operation of appliances that require higher loads (e.g. electric sewing machines), their potential benefits are due mainly to the direct effect. Other important applications of PV technology are (bigger) PVS for schools, health centers, and community centers, water-pumping systems for irrigation, animal and human water supply, as well as PVS for electric fencing.

The following results are based on the investigation of SHS and PVS for schools and community centers. PVS explicitly designed for productive applications (like electric fencing and irrigation) were not considered:

Quality of life: SHS users are usually highly appreciative of their SHS, mainly because it increases their quality of life. Easy access to illumination at any time substantially relieves their daily burden and enhances all types of domestic activities. Since electric lighting substitutes for indoor burning of kerosene or diesel for illumination purposes, SHS considerably improve the sanitary and health situation of household members. The vast majority of users appreciate their radio and TV because of the possibility they afford to obtain information as well as because of the new entertainment opportunities. Typically, women and children benefit most from SHS, since they spend relatively more time at home.

Education: *SHS*-based illumination enables children and adults to study during the evening hours at home with constant and high-quality illumination. Still, studying is not a common activity in the evening hours. *PVS for schools and community centers* are a means of improving the quantity and quality of teaching in rural schools. Good quality lighting enhances evening classes for adult alphabetization, and the possibility to use video tapes, TV, and computers generally broadens the scope of teaching. However, these new opportunities are often missed due to coordination problems between the energy ministry (MME), which manages a program for the equipment of schools with PVS (Prodeem), and the education ministry (MEC) and municipalities, which provide the resources to fund teachers and electric appliances.

Income generation: The interviews indicate that, apart from very few exceptions, the use of SHS has not contributed to increasing household income by stimulating income-generating activities (e.g. handicrafts at night). To promote new income-generating activities, two factors are important: i) an integrated rural development policy, including promotion of local management capacities, access to markets, education and basic infrastructure services other than electricity; ii) usually greater amounts of electricity than are provided by a typical SHS.

Recommendations

The **first issue** addressed here is the question of whether promotion of PVS projects for rural electrification should be a priority area for development cooperation:

Two main arguments are usually advanced in favor of the promotion of PVS projects: first, their contribution to global climate protection; second, their contribution to poverty reduction, due to stimulation of economic and social development in rural areas.

Climate protection cannot be the main argument for promoting rural PVS, since their contribution to the reduction of global greenhouse gas emissions is relatively small (PVS are suited for sparsely populated rural areas with low electricity demand). Aside from this, the costs of emission avoidance are relatively high compared to other RET, e.g. wind or small-scale hydro energy.

As regards their contribution to poverty reduction, the empirical study has shown that SHS and PVS for schools and community centers successfully contribute to improving beneficiary quality of life and health conditions. As far as the economic dimension of poverty is concerned, the systems typically did not stimulate income-generating activities.

Furthermore, supply of a new and relatively expensive technology to a rural population with low purchasing power and low educational levels is often faced with considerable problems. The special barriers typical of structurally weak regions make it difficult to guarantee the long-term technical and financial sustainability of PVS projects and, in many circumstances, call for a substantial share of subsidies.

All these arguments plead for the position that promotion of PV technology for rural electrification should not be a priority field for German development cooperation. Nevertheless, in certain niches PVS can be an economically and ecologically rational measure to electrify the rural poor, considerably improving their basic living conditions. But to trigger broader development effects (income generation, political participation), PVS should be integrated, as one element, into a broader rural development strategy for poverty reduction.

The **second issue** addressed here is the following question: If PVS for rural electrification are promoted, what should be done?

Once a decision to promote PVS projects has been taken, development cooperation should focus on the following three lines of action: i) develop an adequate regulatory framework for rural electrification with PVS; ii) develop and implement sustainable delivery models for PVS adapted to the regional context; iii) integrate PVS projects in broader strategies for rural development in order to maximize development impacts.

Regulatory framework: Measures at the regulatory level have to aim at the elimination of existing institutional, political, and economic barriers to rural electrification projects using PVS. It is therefore especially important to create a level playing field for PV technology in the electricity sector.

Sustainable delivery models: There is no one single best-practice delivery model, because every model needs to be adapted to the existing political, social, and economic conditions of a given region as well as to the individual characteristics of the implementing organization. However, the following key points may be noted:

- coordination of projects with the sectoral framework (observation of grid extension plans and price signals of grid electricity) and use of PVS as a least-cost technology;

- integration and promotion of local structures (capacity-building of users, building on existing local organizations for coordination and management of maintenance services, development of local markets for spare parts and appliances);

- formalization of the delivery model, quality control, and organizational learning (formal contracts and receipts for payments, standardization of components and monitoring of installation).

Under the specific **Brazilian** circumstances related to the ongoing universalization process and the given regulatory framework, the *service model via concessionaires* appears to be the most adequate approach, since it can guarantee access to the necessary financial resources, leads to coordination with grid extension, and ensures the use of PVS as a least-cost technology. Such an approach could make use of existing organizations experienced in the local management of PVS projects as delegated service providers (sub-contractors) of the concession holder. Financial sustainability at the concession area level can be achieved thanks to the financial equilibrium criterion (*equilibrio econômico-financeiro*) established by the regulatory agency ANEEL in setting tariff levels.

However, unless the uncertainties related to regulation of the financing of universalization and the quality requirements for PVS are overcome, Brazilian concessionaires will not engage on any larger scale in off-grid PVS projects. Furthermore, resistance to and lack of experience with PVS projects among concessionaires constitute a problem that has to be tackled. In addition, special attention should be paid to the integration and promotion of local structures, since concessionaires typically do not have a local base in remote areas.

Rural development strategy: Well-adapted and well-managed PVS projects are usually not sufficient to achieve significant economic rural development impacts. Experiences show that provision of electricity to structurally weak regions does not automatically lead to the desired catalytic effect on regional development. What is needed to stimulate broader rural development is coordinated and decentralized approaches that are open to the technological energy solution envisaged (options: SHS, community *and* productive use of PVS, small scale hydro, biomass, grid extension, etc.) and encompass various fields of action (infrastructure, institutions, education and training, access to markets, etc.). Thus efforts have to be made to develop and implement integrated rural development strategies, of which PVS can and should be one element.

I. Preliminaries

1 Background, Objectives, and Structure of the Study

Environmental and climate protection as well as the related challenge of implementing sustainable energy supply systems are issues of great importance in current development cooperation. At the 2002 Johannesburg Earth Summit, the German Ministry for Economic Cooperation and Development (BMZ) announced a Renewable Energies for Development Program with a total volume of 1 billion euros for the promotion of renewable energy technologies (RET) and energy efficiency measures in developing countries.[1]

Another central challenge for development cooperation is to provide basic infrastructure for the poor.[2] The lack of basic infrastructure services is especially pronounced in rural areas. The traditional neglect of these areas, known as "urban bias", is a common phenomenon in almost all developing countries. About 75 % of the world's poor, and also the majority of the estimated 2 billion people who lack access to electricity, live in rural areas.[3]

Thanks to technological progress, RET are becoming an increasingly attractive solution for rural electricity supply. This is especially true for solar photovoltaic technology, which is used in so-called off-grid photovoltaic systems (PVS) to supply sparsely populated areas with no access to the national grid. It is estimated that by the year 2000 more than 1.3 billion PVS for residential use had been installed in developing countries, the vast majority of them in the 1990s.[4] In this study attention will therefore be centered on the use of PVS for rural electrification.

The attractiveness of using RET for rural energy supply is rooted in the possibility to take advantage of a potential win-win situation: one that makes it possible on the one hand to enhance rural development by supplying a wider segment of the rural population with electricity in an economically viable manner and on the other hand to avoid harmful ecological effects that result from conventional technologies.

Nevertheless, there are some important questions open concerning how to use these potentials adequately to ensure that this win-win situation actually takes shape. Experiences from different developing countries indicate that several electrification projects with PV technology have failed to achieve technical and financial sustainability. The main purpose of this investigation – which is based on a case study for Brazil – is therefore to provide an orientation for development cooperation concerning best practices to promote sustainable electricity supply with off-grid PVS.

The **main research questions** are:

1. What are the best ways to organize and manage off-grid PVS projects (which delivery model to chose) to achieve technical reliability and cost effectiveness in electricity service?

2. What influences do national regulation of the electricity sector and national electrification policies have on the dissemination and sustainability of rural electrification on a PVS basis?

3. What effects for rural development can be achieved through electrification, especially as regards the limited generation capacity of PVS?

1 The plan is to spend this amount during the next five years. See http://www.bmz.de. In this context, the German government will host the International Conference for Renewable Energies that will take place in Bonn, from June 1 to June 4, 2004. See http://www.renewables2004. de.

2 This is the main topic of the World Development Report 2004. See World Bank (2003).

3 See IFAD (2002), p. 16; Brook / Besant-Jones (2000), p. 2.

4 See Nieuwenhout et al. (2001). PVS for residential use are called solar home systems (SHS).

The present study explores these three questions both conceptually and by means of an empirical investigation of the Brazilian case,[5] with emphasis on the first question. Brazil is especially suited for this investigation because it offers good climatic and geographic conditions for the use of PVS. Furthermore, several PVS projects with different delivery models have been implemented there during recent years. Finally, recent legislation has formulated a political commitment to providing universal access to electricity service. This could act as a catalyst for disseminating PVS in rural areas.

The present study breaks down into four parts and 13 chapters:

Part one prepares the ground for the following conceptual and empirical analysis of the main questions. Having outlined the research methodology (Chapter 2), it provides a brief overview of the arguments in favor of an increased use of renewable energy sources (Chapter 3). Chapter 4 presents and discusses the different technical options for rural electrification and the pros and cons of these alternatives and concludes by setting out the conditions under which PVS constitute a rational choice. Finally, Chapter 5 provides an overview of typical barriers to rural electrification with PVS.

Part two analyses conceptually the main questions of this report, laying the groundwork for the empirical section that follows it. To this end, Chapter 6 presents and discusses the typical structure of the electricity industry and its implications for rural electrification. This is followed by an attempt to classify and judge alternative approaches to rural electrification with PVS, focusing on optional delivery models at the micro-level and the main regulatory issues at the macro-level (Chapter 7). Chapter 8 gives an overview of the anticipated rural development impacts of electrification via PVS.

Part three presents the results of the empirical investigation conducted in Brazil. It starts out with an introduction to the Brazilian electricity sector, referring to the legal, economic and political conditions for rural electrification and addressing in particular both the recent legal initiative to provide for universal access and the remaining open questions in relation to the use of PV technology (Chapter 9). Chapter 10 briefly discusses the socioeconomic conditions in the regions covered by the field study. Chapter 11 then describes and assesses comparatively four projects that were visited, looking into their organizational features and the issue of technical and financial sustainability; this is followed by a conclusion regarding some key factors for achieving sustainability in PVS projects. The results regarding rural development impacts are presented in Chapter 12.

Part four (Chapter 13), based on the previous findings, presents recommendations for German development cooperation.

2 Methodology

The following chapter outlines the study's methodological approach. The study's intent was first and foremost to draw conclusions on the promotion by development cooperation of PV technology for rural electrification under the conditions specific to Brazil. Beyond that, more generalized conclusions are drawn on rural energy supply via PVS that are independent of the specific Brazilian case.

The first step was a review of the literature and international project documents on PV technology, rural electrification, and development impacts as well as on sectoral and regulatory framework issues; this was used to define the conceptual framework and the three main problem dimensions of the study (see below). The findings were discussed with experts from Brazil, the KfW, and the GTZ.

5 Empirical investigation focused on three Brazilian states: Alagoas, Bahia, and Minas Gerais.

The empirical study was carried out during a stay in Brazil from February 17 to April 30, 2003, and consisted of expert interviews conducted in the state capitals as well as interviews with users and local managers during the field stays. The field study focused on Northeast Brazil.[6]

The empirical analysis generally followed a qualitative approach. Thus the results presented in Chapters 11 and 12 are based to a good extent on what might be called "typical cases" and are not representative in the strictly quantitative sense.[7] The research objectives and time restrictions involved made it difficult to examine a number of cases that would be sufficiently great for quantitative empirical analysis. Data validation by means of triangulation and comparative research was therefore used to achieve reliable results.

All told, 131 interviews were conducted: 43 with experts and project managers; 88 with PVS users. Of the user interviews, 32 were conducted in Bahia, 29 in Alagoas, and 27 in Minas Gerais.

Problem Dimensions and Research Activities

The purpose of the present study is to answer the main research questions (see Chapter 1) and to provide practical orientation for development cooperation in the form of best practices to promote sustainable electricity supply with off-grid PVS, based on a case study for Brazil.

To reach this goal, the authors chose a relatively broad approach along the following main problem dimensions. The problem dimensions were analyzed both conceptually (Part two) and empirically (Part three):

- Sectoral conditions
- Project management
- Development impacts

The **sectoral conditions** involved are principally legal, but also political and economic aspects of the electricity industry that affect the rural electrification process. The sectoral conditions set the rules at the macro-level and thus serve as the basis on which rural electrification and PVS dissemination takes place. Assessment of the sectoral conditions is especially important in the Brazilian case because they are presently undergoing profound changes and are closely related to the amount of resources available for financing rural electrification.

The main purpose as regards the sectoral conditions was to identify the principal bottlenecks that are impeding a widespread use of PVS for rural electrification.

A number of structured expert interviews were conducted in order to explore the Brazilian sectoral conditions. The interview partners included representatives from academic institutions, regulatory agencies, federal and state ministries, municipalities, NGOs, as well as from the electricity and renewable energy industries.[8]

Project management is concerned with the aspects of organizing and financing PVS projects at the micro-level as well as with coordination of the delivery model with given sectoral conditions. The present study places special emphasis on the investigation of this dimension, as can be seen from the size of the related conceptual and empirical Chapters, 7 and 11. Project management is the dimension essential for the achievement of technical and financial sustainability. The central subcategories empirically explored on the basis of a comparison of four different practical delivery models are: i) marketing, i.e. the choice of actuation area or definition of the local market; ii) installation of the PVS; iii) maintenance of the PVS; iv) information and capacity-building activities; iv) financing of the costs related to the preceding activities.

6 See Ch. 10, especially Map 1.

7 On the pros and cons of quantitative versus qualitative approaches in practical empirical analysis in developing countries, see Neubert (2003).

8 See Annex A2 for the list of institutions interviewed.

The main purpose was to describe and assess the four PVS projects visited, with a view to judging their achievement of technical and financial sustainability and to drawing conclusions on key issues that have to be considered when designing and implementing PVS projects.

Of the projects visited, two are located in Bahia (Chapters 11.1 and 11.3), one in Alagoas (Chapter 11.2), and one in Minas Gerais (Chapter 11.4). The empirical research relied primarily on structured interviews with project managers, local managers, maintenance and installation technicians, and standardized user interviews.[9]

Development impacts are an issue crucial to assessing the success of a development project. Rural development is a multifactorial process, and the effects of energy provision are hard to isolate. The potential development impacts of rural electrification relate to its direct effect on basic needs and activities as well as its indirect effect on income generation and employment, and they depend on what application the energy service is designed for. One specific feature of PV technology is that it is suited to supply only relatively small loads, a factor which limits its applicability for income-generating activities. Typical applications are lighting, radio and TV, small domestic appliances, water pumps, electric fences, refrigerators, telecommunication and computers. The relevant development categories analyzed are i) quality of life (including health, security, relief for hard daily activities, information and entertainment), ii) education, iii) gender, and iv) income situation.

The main purpose was to assess the impact of PVS-based electrification on the development categories mentioned.

The empirical investigation was limited to PVS for residential use (so-called solar home systems – SHS) as well as to PVS for schools and community centers. PVS explicitly designed for productive applications (electric fences, irrigation) were not considered. The empirical results are based on standardized user interviews[10] as well as on structured interviews with project managers and experts.[11]

9 See Annexes A2 and A3 (user questionnaire).

3 Ecological Benefits from the Use of Renewable Energy Technologies

The 1987 Brundtland Report defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”[12] RET facilitate sustainable development by reducing consumption of limited resources and by preventing environmental damage.

Increasing the share of energy generated by RET[13] implies a substantial change in the present energy matrix. Still, the by far greatest share of the world's primary energy is generated by burning limited fossil fuels, a practice which causes severe environmental contamination.[14] The most harmful effect is the emission of greenhouse gases (GHG) which affect the global climate. The Kyoto protocol, signed in 1997, aims at a reduction of GHG emissions. Although still not in force, the Kyoto protocol prescribes a first step towards a considerable change in the energy matrix. As this study concentrates on electricity supply, special emphasis is given to the role of the electricity sector. The demands of the Kyoto protocol can be reached

10 See Annex A3.

11 See Annex A2.

12 World Commission on Environment and Development (1987), p. 43.

13 RET can be distinguished in terms of the energy source used: Solar energy, wind energy, geothermal energy, biomass, energy from oceans and hydro-energy. See Wilkins (2002), p. 7. Big-scale hydroelectric power plants are excluded from the following analysis, since they often lead to substantial negative externalities at the local level (destruction of ecosystems, resettlement of local residents, etc.). See Scholz et al. (2003), Ch. 4.

14 In 1997 the share of oil, gas, and coal in primary energy supply was 88 %. See Wilkins (2002), p. 6.

through the enhanced use of RET for electricity generation, since RET neither consume limited energy resources nor emit GHG.[15] Apart from this, efforts to raise energy efficiency are needed to avoid energy waste due to inefficient final use appliances, poorly working power grids, and outdated power plants.[16]

The use of RET avoids negative externalities at the local and the supra-local level:

The **local level** refers to the area directly affected, i.e. where RET are in use. The central focus of the present study is dispersed rural areas. In rural areas of developing countries biomass is commonly burned as a source of energy for cooking and kerosene or diesel are often used for lighting purposes. When biomass or fossil fuels are burnt indoors, the result may be severe health damage such as respiratory illnesses stemming from the attendant smog and gas emissions. Biomass is usually collected in the surroundings of settlements, and this often leads to deforestation. The consequence is advancing desertification and declining soil fertility.[17]

Another common energy source in rural areas is dry-cell batteries, which are used for radios or other small appliances. Disposal of these dry cells usually means simply discarding them on the ground. This seriously pollutes soil and water. The use of RET in rural electrification displaces a lot of dry-cell batteries and thus avoids contamination.

Long-distance grid extensions not only cause huge costs but also constitute a significant ecological burden by harming local ecosystems. Off-grid power generation, usually powered by RET, avoid these harmful effects of long-distance grid extensions.[18]

At the **supra-local level,** reduced emissions of GHG are the most important improvement resulting from RET. GHG emissions are an important factor involved in the rise of the average air temperature on earth. If this trend continues, severe climate changes must be expected that threaten the natural life-support systems of millions of people.[19] Climate protection is a global public good, one which has to be provided by industrialized and developing countries alike. The increased use of RET helps to reach this goal. It has to be stressed, though, that electricity consumption in rural areas is low and that for this reason the potential for using RET for rural electrification to avoid GHG emission is limited. This potential is higher in urban, industrialized areas.

Another important negative effect that can be reduced by using RET is the harm caused to forests and crops by acid rain. Burning conventional fossil fuels releases oxides of nitrogen and sulfur, and this is one of the important causes of acid rain.[20]

To sum up, substitution of RET for conventional energy technologies can help to avoid a number of negative externalities.[21] Still, RET are not used on a large scale, either in industrialized or in developing countries. One important reason is that electricity prices usually do not reflect the negative external effects caused by conventional energy technologies. This fact lowers the competitiveness of RET relative to conventional technologies.[22] To

15 Generating electricity by RET avoids three of the six most important GHG identified in the Kyoto protocol – carbon dioxide, methane and nitrous oxide – which all result from burning fossil fuels and biomass. See Wilkins (2002), p. 34.

16 See Schmitz (2002), p. 5.

17 See Oliveira (2001), p. 53.

18 See Wilkins (2002), p. 32.

19 See WBGU (2003), Chapter 4.3.1.2.

20 See Wilkins (2002), p. 32.

21 RET may also give rise to negative external effects, though, e.g. noise (wind power plants), disposal of toxic batteries (photovoltaic systems), etc.

22 Some countries have established legal frameworks that help to internalize the negative externalities. One example for the electricity sector is the German Renewable Energy Law (Erneuerbare Energien Gesetz) which prescribes a subsidy mechanism for electricity generated

encourage the use of RET in developing countries, the international community has set up some special financing mechanisms. The most important are the Global Environment Facility (GEF) and the Clean Development Mechanism (CDM).[23]

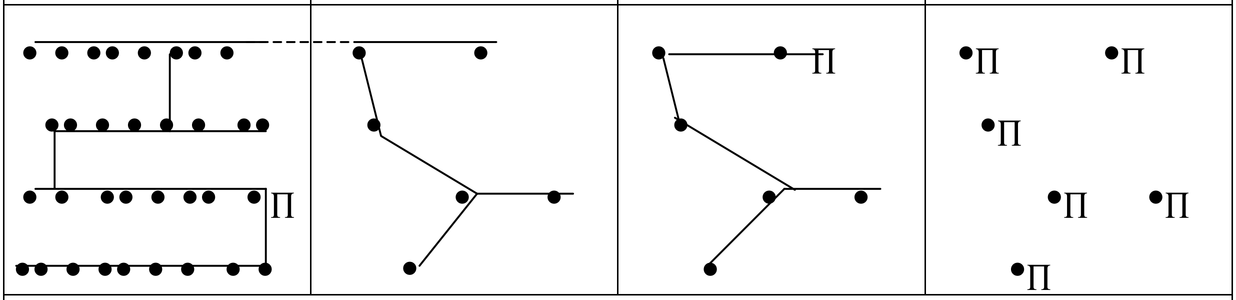
The ecological impacts and benefits of RET, especially PVS, will not be examined empirically in this study.

4 Technical Options for Rural Electrification

Even though this study mainly concentrates on PV technology for rural electrification, the following section will give an overview of the most common, technically feasible alternatives for rural electrification. After outlining the basic alternatives of grid and off-grid electricity supply, the following section will sketch some of the options available for off-grid electricity generation.

Figure 1: Technical Alternatives for Rural Electricity Supply

Urban	Rural		
Grid	Grid extension	Off-grid supply	
		Local Area Grid	Stand-alone System



Legend: ∏ = electricity generating unit
• = electricity consuming unit
--- = connection to national grid
— = power line

Source: Own illustration

4.1 Grid versus Off-grid Electricity Supply

There are basically two technical alternatives for electricity supply to rural areas: the first is extension of the national grid to rural areas in order to provide consumers with a central supply of electricity, usually generated in large power plants. The second is autonomous electricity generation and supply, that is, either the feeding of electricity from small power plants into a local area grid or the use of "stand-alone" systems that serve one particular consumer only. Figure 1 illustrates these technical alternatives for rural electricity supply.

through RET. For a discussion of the German Renewable Energy Law, see e.g. Flandrich / Grewe (2003).

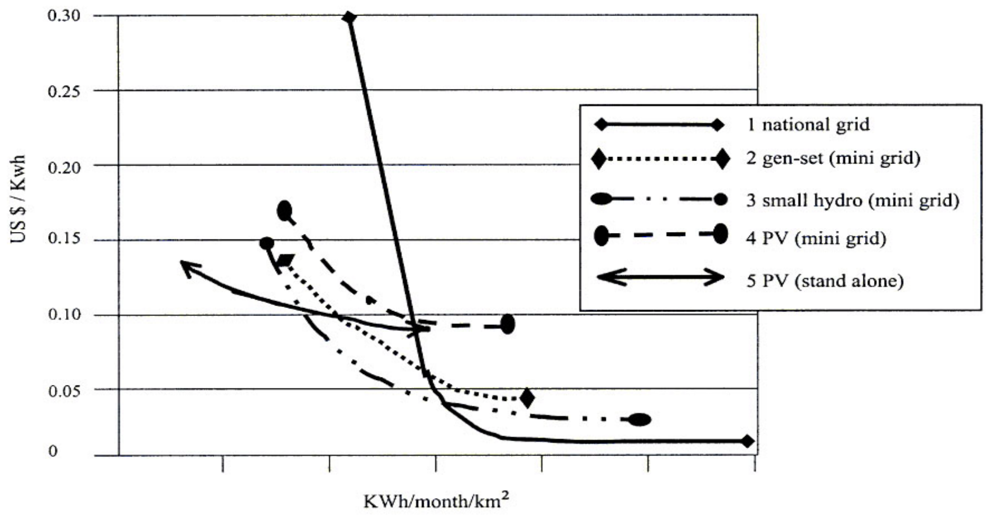
23 The GEF was created in 1992 as financing mechanism of the Framework Convention on Climate Change and on Biodiversity. It is jointly managed by the World Bank, UNDP, and UNEP. See WBGU (2003), p. 41 ff. The CDM provides emission certificates for enterprises from industrializing countries investing in RET in developing countries as a means of fostering the decisions of the Kyoto protocol. For a comprehensive outline of this mechanism see Wilkins (2002), p. 37 ff. Since GHG emission avoidance by the use of rural PVS is quite low and certification costs are relatively high, it is to expect that rural PVS projects will not benefit from CDM under current conditions.

Which alternative involves lower costs per unit of electricity consumed depends mainly on a) the dispersion of consumers, b) their distance from the existing grid, and c) the level of demand. Figure 2 depicts the influence of the electricity consumption density[24] (kWh/month/km^2) on the dynamic lifespan costs of electricity supply for different supply technologies. It is evident that different consumption density levels correspond to different least-cost supply technologies. Off-grid technologies, especially PVS, are suited for very low consumption densities.

Remote rural areas in developing countries are often characterized by a high dispersion of consumers, with long distances to the next larger-sized village. Due to their socioeconomic conditions, rural households can usually only afford small electric appliances like lamps or a radio. As a result, their overall demand for electricity is low, which means low load factors for the supplying technology. This implies that rural areas often have a low electricity consumption density. Electricity is mainly used at night for lighting, entertainment (like television and radio), and seasonal agricultural purposes, the result being daily and seasonally fluctuating demand patterns.

For such areas, extensions of the existing national grid may not be the most economical supply alternative (see Figure 2). High investment costs for the construction of lines and substations run up against low and dispersed demand. This reduces the cost-cutting effect of the economies of scale which can be realized when electricity demand is high and concentrated. Investment costs rise as a function of distance to the existing grid. Another point that lowers the economic viability of grid electrification in areas with low consumption density is technical and non-technical power losses. Technical power losses occur during transmission. The extent of these losses depends on the voltage and the length of the line. In addition, non-technical losses in revenues result from illegal connections and administrative irregularities such as meter-tampering or collection arrears. Political

Figure 2: Dynamic Lifespan Costs of Different Supply Technologies



Source: Adapted from Suding / Posorski (2002), p.15

24 Electricity consumption density combines the factors a) dispersion and c) demand level.

pressure often sets limitations on the ability of utilities to take remedial action.[25] All these factors together render the recovery of investment costs difficult and risky.

Autonomous off-grid supply, the second alternative, does not need transmission and distribution networks, since in this case electricity is generated close to final demand. Nevertheless, the initial investment costs for the local generating system are still considerable (see Table 1). The generation system is designed to meet low levels of demand. As a result, capacity is limited, which may possibly result in unsatisfied electricity demand at peak times. System dimensioning is therefore crucial. The various off-grid technologies will be discussed in Chapter 4.2. Off-grid systems lose their competitive advantage relative to grid extension when consumption density increases (see Figure 2).

Consumers may prefer grid extensions for different reasons: grid extension provides the consumer with non-intermittent electricity, with almost unlimited capacity (from a individual point of view). Apart from this, usually the fees paid by rural grid consumers for the electricity they consume do not cover all costs incurred, as this electricity is subsidized by government or cross-subsidized through urban sales.[26] This subsidization is not that common for off-grid systems. For these reasons, unconnected consumers may be reluctant to accept off-grid electricity. They may fear dropping back in their eligibility ranking for grid extension once they are considered "electrified" through off-grid electrification.

From an ecological standpoint, off-grid distribution has advantages because it often draws on RET. Generally, the political preference is for grid extension, though, because large-scale building of electricity generation capacity is considered as a measure of significance for national economic development.

25 See Ramani (1995), pp. 160-163.

26 See Chapter 7.2.1.

4.2 Technical Options for Off-grid Electrification

In contrast to grid extensions, the capacity constraint of decentralized (off-grid) supply is more immediate, and the responsibilities of users are generally greater (the range of possible responsibilities comprises the roles of operator, maintainer, and owner).[27] Such greater self-reliance may be preferred by users, but it can also limit the diffusion of the systems. In particular if the initial investment costs have to be borne at the user level, that is, either by the community or by the household, they can act as a limiting factor. Another limiting factor may be the lack of specific operation and maintenance skills in rural areas.

Decentralized electricity generation can draw on a number of different technologies. These technologies can be categorized as conventional and renewable:

The **conventional** system used for off-grid power supply is the diesel generator. Diesel generators do not depend on specific locational characteristics and can provide non-intermittent electricity. They do, though, depend on constant fuel availability. The amount of electricity supplied per generator is fixed, and thus often only a certain share of it is used, a factor which increases fuel costs per unit of electricity used. In consequence, this method is typically only used in times of high electricity demand, such as in the morning and evening.

Diesel generators lose their cost advantage compared to other technologies when capacities under 2 kW are involved.[28] For remote areas, transportation of diesel fuel and lubricating oil as well as maintenance requirements raise dynamic costs to at least US $ 0.3/kWh. That is two to three times the cost of grid-supplied electricity in urban areas,

27 See discussion in Chapter 7 for off-grid PVS.

28 To illustrate this capacity: modern steam irons or vacuum cleaners need aprox. 1.5 kW.

but is still cost-effective relative to rural grid extensions.[29]

Renewable Energy Supply Technologies

In economic terms, RET have to compete with the currently available diesel generator technology. In contrast to diesel generators, most RET rely on intermittent resources and therefore require additional investments in (conventional) back-up systems to ensure continuous electricity supply (e.g. batteries). Some renewable energy technologies depend on specific locational characteristics. In general, their initial investment costs are greater than those of diesel generators.

Since there is a wide and diverse range of RET available, only the most prominent ones will be presented here. It is difficult to make any generalizations on their technical performance and costs, since these vary from one location to another. Table 1 gives a general overview of their cost characteristics.

instead of oil imported into the region. As opposed to most other RET, biomass technologies do not rely on a naturally intermittent energy source (wind, sunlight) and are not dependent on highly specific locational characteristics. Still, biomass technologies may be faced with fuel availability constraints. If biomass is used on a significant scale and/or as a single source of energy, large areas of land have to be dedicated to the growing of source fuels. But land and crops may have other non-energy uses (e.g. food production). Another point is that the availability of biomass may show seasonal fluctuations.

Compared with diesel technologies, both initial investment costs and operation and maintenance costs are higher. Biomass technology can therefore be more cost-effective than diesel technology only when diesel fuel costs are fairly high (0.35-0.40 US $/liter or more), which often is the case in extremely remote areas.[31]

Biomass may be carbon-neutral if the entire crop is used for energy generation (short carbon cycle).

Table 1: Cost Characteristics of Renewable Energy Technologies

	Turnkey investment cost (US $/kW)	Current energy cost (US $/kWh)	Potential future energy cost (US $/kWh)
Small-scale hydropower	1,200 – 3,000	0.04 – 0.10	0.03 – 0.10
Wind power	1,100 – 1,700	0.05 – 0.13	0.03 – 0.10
Photovoltaic	5,000 – 10,000	0.25 – 1.25	0.05 – 0.25
Solar thermal	3,000 – 4,000	0.12 – 0.18	0.04 – 0.10
Biomass	900 – 3,000	0.05 – 0.15	0.04 – 0.10

Source: Adapted from Turkenburg (2000), p. 266

Biomass technologies are based on resources such as wood, crops, and animal waste.[30] One advantage of this technology is the possibility it offers to use locally available biomass as fuel

But sustained production on the same area of land may have considerable negative impacts on soil fertility, water use, biodiversity, and landscape.[32]

Small scale hydropower can be used to serve a small community or a number of communities

29 See Goldemberg (2000), pp. 368-389.

30 The usual distinction is between plant and animal biomass. Plant biomass can be woody and non-woody biomass, processed waste and fuels. Animal biomass includes animal manure.

31 See Goldemberg (2000), p. 378.

32 See Turkenburg (2000), p. 255.

through a local area grid. Hydropower uses the energy of flowing water and variations in the altitude of the terrain to generate electricity. The power potential of water depends on the volume of water of a river (the flow) as well as on the differential between the levels at which water can flow (the available "head").

The main limitations of small-scale hydropower are its dependence on specific locational characteristics, its high capital intensity,[33] the need for technical maintenance skills at dispersed locations, and the seasonality of water flows, which may require a diesel back-up.[34] In addition, low load factors (day demand is often only 10 % of evening demand) significantly raise the technically feasible minimum costs of 0.05 US $/kWh that can be realized when the system is used at full capacity. Therefore, despite saving fuel costs, small-scale hydropower appears too costly as a means to cater to dispersed rural consumers with little demand.

In cases in which flooding is necessary to assure a regular water flow, negative environmental effects may result from ecological system changes up- and downstream of the plant.

Wind power can be used to serve either a small community through a local area grid or a single household. The amount of electricity a wind turbine produces depends on wind speed and rotor diameter. Thus the use of wind power is highly site-specific and requires a minimum average wind speed. To ensure non-intermittent electricity supply, usually diesel back-up systems are necessary, a factor which significantly drives up the costs.[35] These back-up systems are not necessary when wind power plants are connected to the grid (which is the most common application of wind power technology).

Environmental effects depend on the backup system that is used. The positive effects of the clean wind power technology are reduced when it is combined with the use of diesel generators.

Photovoltaic systems can be used for different purposes and applications.[36] The most common application is to serve a single household as a solar home system – SHS (see Box 1 and Annex A1 for more information about the features of SHS). PVS are suited to supply highly dispersed consumers. The disadvantages of PVS include the high initial costs of the system[37] and its dependence on sunlight, an intermittent resource. But since intermittence follows regular patterns, batteries can be used to store energy instead of having to rely on diesel back-up systems. The advantages of PVS include the relative low intensity of maintenance needed and the possibility to adjust system capacity to meet demand. PVS therefore appears to be an economically viable alternative to supply highly dispersed consumers with electricity.

The environmental effects are mixed: PVS generate energy without emitting GHG. Still, the use of batteries is environmentally harmful.[38] Another point that limits the environmental benefits of PV technology is the fact that production of PV cells means higher (conventional) energy consumption in relation to the energy produced during the lifespan of the system as compared with other RET (wind power, water power).[39]

33 Initial investment costs depend on capacity, location (site topography, proximity of the site to the main load area, and hydrological conditions) and quality.

34 See Ramani (1995), p. 180.

35 See KfW (1998), p. 12. With local assembly of good quality costs for off-grid wind power are in the range of US $ 0.50/kWh. See Suding / Posorski (2002), p. 15.

36 PVS may be used for battery charging stations, to serve individual households (SHS) or bigger community buildings like health centers and schools (community systems), for water-pumping, for electric fences, etc.

37 See Ramani (1995), p. 180.

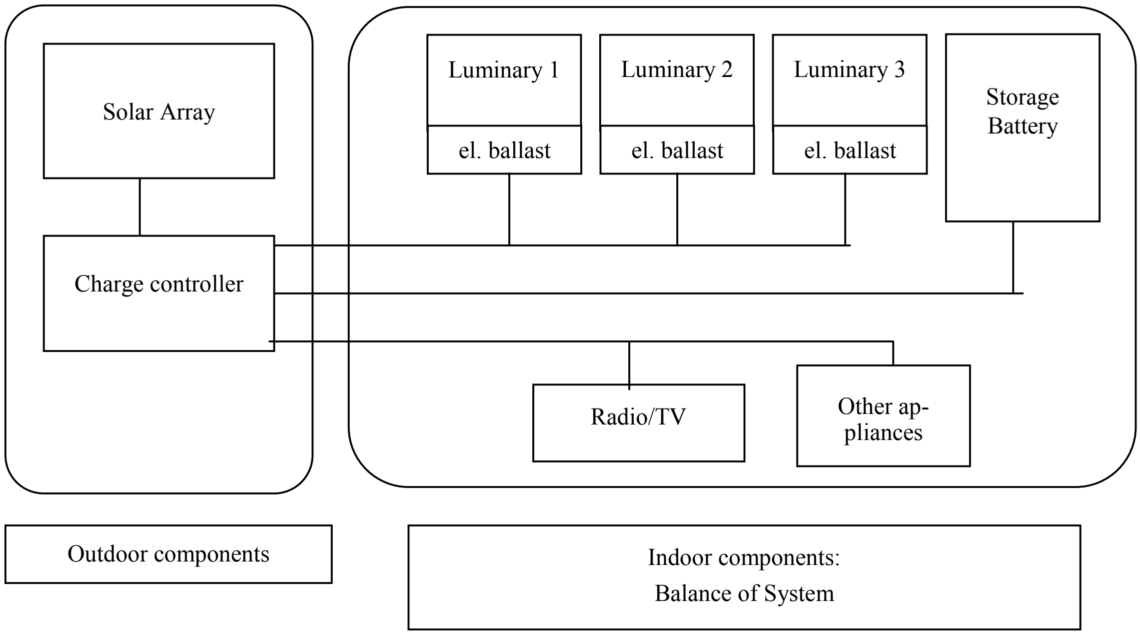
38 Battery disposal has ecologically harmful effects which grow with the number of batteries used. These can be lowered by ensuring proper treatment, thus increasing active battery life, controlled disposal, or a recycling system.

39 See KfW (1998), p. 18 f.

Box 1: Technical Design and Characteristics of a SHS or Community PVS

A SHS or a Community PVS consists of two major components:

- ***The solar generator***, which is made up of an array of one (or more) photovoltaic panel(s) and the battery charge controller (optionally, an additional inverter to transform direct current (DC) to alternating current (AC) and to operate the whole system with AC can be installed);
- ***the Balance of Systems (BOS)***, which includes the battery bank and all domestic installations like cables, switches, clips, fixtures, sockets etc. as well as the (DC or AC) appliances like fluorescent lamps, radio, TV and other small appliances. The electronic ballast is necessary, when an inverter does not exist.



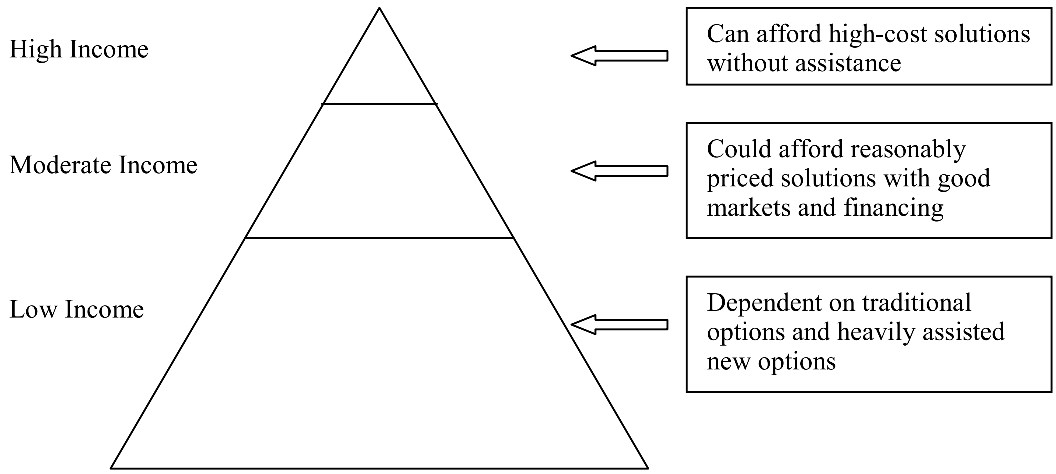
From a financial perspective, the distinction between BOS and the solar generator is important for those cases, in which the SHS serves as collateral for a financial institution. Usually, only the solar generator serves for this purpose, as the BOS parts become property of the user with the down-payments.

Source: GTZ (2001), p.11

If we compare the different alternatives for off-grid electricity generation, PVS seem to be a good choice for highly dispersed consumers with low demand. PVS are economically advantageous for households which spend more than US $ 2.5 monthly on candles, oil, kerosene, or dry-cell batteries and which need a capacity of less than 2 kW. Cost effectiveness is reached at the very lowest scale (typically less than 100 W)[40] in areas with no access to the grid, where demand is characterized by low levels. In such regions even diesel electricity is not competitive. Another advantage of PVS is that they are less location-specific than hydropower and wind power. And furthermore, they are not faced with restrictions on resource availability like biomass, and unlike diesel generators, they can operate at very low scale.

40 See Goldemberg (2000), p. 376.

Figure 3: Energy Solutions for Rural Populations



Source: ESMAP (2000), p. 21

5 Barriers to Rural Electrification with Photovoltaic Systems

This chapter will discuss some barriers[41] that policies for rural electrification with off-grid PVS have to face. One of the main and typical difficulties encountered in providing electricity to rural areas in developing countries is the substantial share of low-income households involved. This implies that ability to pay is commonly too low to cover the full costs of any (even least-cost) supply technology, and hence the demand of such households cannot be met in a market setting. The dilemma is that in rural areas economies of scale do not work because of low consumption density (see Chapter 4), which makes supply more expensive, and, at the same time, rural areas are characterized by low-income situations, a factor which limits household ability to pay. This constellation can be considered a case of market failure and justifies the use of subsidies to reach the rural poor with electricity services, unless it is regarded as sufficient to supply only relatively wealthy rural households.

As Figure 3 shows in a schematic manner, usually only a small share of the rural population is able to afford electricity services (e.g. off-grid PVS) without assistance.[42] In many developing countries, the challenge is to establish organizations and financing mechanisms to reach the lower layers of the pyramid. Parts two and three of his report deal mainly with different approaches to meeting this challenge.

More generally speaking, barriers to rural electrification with off-grid PVS can be broken down into economic, informational, and institutional barriers. Usually the barriers are interrelated, and thus it is difficult to isolate individual influences. Some of these barriers have to do with the general problem related to the introduction of a new technology, i.e. the need to build up a new infrastructure for dissemination of information, promotion, distribution, installation, and maintenance.[43]

Economic barriers are related to the costs of service provision, socioeconomic conditions of demand and macroeconomic issues. Some of them

41 See Wilkins (2002), p. 120 for a discussion of the term "barrier."

42 See Reddy (2002), p. 121 for illustration of this issue for Indian conditions.

43 See Campen/ Guidi/ Best (2000), p. 9.

are due to market failures, others are caused by government policies. Aspects related to the structure of the electricity sector will be addressed among the institutional barriers.

- The main economic obstacle is the high initial investment cost, which implies relatively high average costs for electricity. Also, maintenance costs can be considerable, increasing the total cost of supply (see Chapter 11).
- The target group of off-grid PVS commonly is the low-income population, whose ability to pay and creditworthiness are limited.
- Due to this factor, the risk perception of investors is high and capital availability generally is low. This means that there is a shortage of capital to foster off-grid PVS dissemination.[44]
- To overcome the cost barrier, financial institutions are required. Frequently, there are no such institutions in rural areas.
- In rural areas, there is a severe lack of the provider and service networks needed for equipment and after-sales services because of the small size of these markets. This lack of agents impedes sales and the technical sustainability of PVS.
- High taxes and import duties on PVS as well as a lack of foreign currency raise costs and impede dissemination.[45]

Information barriers affect both the supply and the demand side. PVS dissemination is restricted by a lack of knowledge about the possibilities and limits involved in the use of PVS as well as about best practices in organization and management.[46] Initiating institutional changes can help to overcome information barriers.[47]

- Rural population, potential service providers (like utilities), and politicians are often not informed about the existence and the potentials of PVS. Therefore, off-grid PVS have difficulty in gaining recognition as an option for rural electrification.
- Where there is information available about PVS, a lack of knowledge about use, maintenance, and limitations hampers PVS provision and operation. This reduces the lifespan and the efficiency of the equipment.
- Examples of malfunctions and missing quality standards lead to prejudices regarding uncertain product quality, a fact which reduces the application potential and the attractiveness of PVS, and consequently the demand for it.
- Information asymmetries complicate private-sector participation and result in a high perceived risk. Since the legal framework for PVS, and especially for SHS, is often unclear and there is little knowledge about the characteristics of potential clients, private utilities usually hold back on investments.

Institutional barriers can be targeted by concrete policies and subsequently pave the way to overcoming some of the above-mentioned obstacles. Typical institutional hindrances are:

- The political commitment to electrifying rural areas is usually lower than that to electrify urban areas, due to high costs and urban bias tendencies.
- Electrification plans therefore often fail to define clear targets regarding the outreach and quality of rural electricity services. In addition, existing laws and regulations are

44 See Tse (2000), p. 6, for an analysis of the Ghanaian PVS projects and its economic barriers.

45 See Schmitz (2002), p. 6.

46 See Wilkins (2002), pp. 129.

47 For a closer examination of information barriers, see Moskovitz (1993), p. 13.

Box 2: Barriers to PVS Dissemination in Egypt and Ghana
Between 1999 and 2001, UNEP carried out a study on barriers to RET in Egypt and Ghana. The study was based on a series of stakeholder workshops in every country to identify the most important RET and subsequently the main barriers to their dissemination. The objectives of the study were to identify relevant barriers in joint discussions of the relevant stakeholders, to explore options for their removal and to strengthen institutional capacity. More experiences should be generated and provided for other countries. The **Egyptian** case highlights the lack of information, the high dissemination costs and a lack of financing mechanisms, high taxes and duties on PVS, the unfavorable tariff system, and ineffective subsidies as the main barriers. Among the stakeholders existed a consensus to primarily attack the economic and financial barriers. The participants of the workshop decided to launch awareness campaigns and to design special financial schemes for the buyers. Manufacturers and suppliers obligated themselves to open representatives near the consumers to improve maintenance. The government promised to design new market incentives for the dissemination and to integrate PVS electrification programs in other development programs. In **Ghana**, the high start-up costs have been identified as the main barrier. Therefore, the main action accorded was to devise new and creative financial schemes to enhance PVS dissemination. The government committed itself to integrate PVS in development and electrification programs. Moreover, awareness campaigns to show the possibilities of PVS and education and capacity building programs to enhance knowledge on PVS were agreed upon.
Source: Painuly/ Fenhann (2002)

poorly targeted or enforced. This is due to unreliable and inefficient regulatory institutions. As a consequence, electricity providers in rural areas often do not show much commitment to expanding access.

- Inconsistent rural electrification policies raise both political and economic risks and transaction costs.[48]
- Lacking signs of government commitment to off-grid PVS (often, PVS are not included in electrification programs) reduce the motivation of other key players to invest in the development of technologies and markets.[49]
- In many countries, there is lack of quality standards for national PVS components. This leads to uncertain or unreliable product quality.
- Exclusive concessions create monopolies, which prevent new providers of decentralized PVS services from entering the market. Hence, if concession holders are reluctant to accept PVS, it is unlikely that they will be distributed.
- Commonly used, and often hidden, subsidies for fossil fuels, especially diesel, make PVS less competitive than they would be without price distortions.

48 See Wilkins (2002), p. 125.

49 See Wilkins (2002), p. 123.

II. Conceptual Basis for the Case Study

6 Sectoral Conditions for Rural Electrification in Developing Countries[50]

Before specific approaches for off-grid PVS projects are discussed (Chapter 7), this chapter will outline the main characteristics of the electricity industry in developing countries.

The electricity industry has traditionally been made up of state-owned, monopolistic utilities. Poor performance of this organizational model in developing countries in terms of quality and service coverage as well as budgetary concerns resulting from a lack of financial sustainability have led to comprehensive reform efforts, which are being supported by international donors. These reforms aim at privatizing and liberalizing former state-run utilities and are leading towards a market-based approach. This new organizational model will reshape the conditions for the entire sector's performance. Partnerships with private agents will provide new options but also considerable challenges for rural electrification programs. On the one hand, attracting private capital and know-how broadens the scope for decentralized approaches using RET such as off-grid PVS. On the other hand, it is unlikely that profitability of rural electrification will be achieved, and thus efficient subsidy and incentive mechanisms will have to be devised if the disadvantaged population is to be served.

6.1 Introducing Competition into the Traditional Market Structure

Provision of grid-based electric power is characterized by a vertically organized supply chain: power generation, transmission and distribution, and customer services. Electricity is generated by converting primary or secondary energy into electric power. The electricity is then transmitted from the power producer via a high-voltage grid over long distances to the local distribution networks, where electricity is transported at lower voltage to consumers. Customer service is responsible for metering, billing, and collection of fees.

Except for customer service, each level is relatively capital-intensive. The high initial investment gives rise to considerable economies of scale and prevents any simultaneous profitable operation of several firms in the same market. When a single supplier represents the economically efficient solution, this industry is a natural monopoly. Traditionally, the overall supply chain of the electricity sector has been considered a natural monopoly. Accordingly, in many developing (and industrialized) countries the power sector still has a market structure dominated by state-owned national power utilities with a legally endowed monopoly and a vertically integrated supply chain. Vertical integration makes sense where economies of scope[51] reduce the costs of coordination between the different functions of the supply chain.

Introducing competition at the generation stage of the supply process has been the first reform step to be undertaken in many countries. Technological progress has reduced the least efficient size of power plants to a tenth of its traditional size, and thus this stage in the value chain no longer qualifies as a natural monopoly. Here, competition in the market is possible. Transmission and distribution of electric energy, however, are still best provided by a single firm, since it is as a rule not profitable to build two parallel networks. These functions may be vertically separated, though, because enhanced information processing has largely eliminated economies of scope.

Regulatory reform must be an integral part of the reform process. An independent regulatory au-

50 This chapter is based on Bacon/ Besant-Jones (2002), Wild (2001), and World Bank (1994).

51 Economies of scope are realized if a single firm is cheaper at producing several distinct goods than several specialized firms at producing the same overall amount of different goods individually.

thority needs to be created to oversee the remaining natural monopolies in order to avoid any abuse of market power. Another function of the regulatory authority is to implement tariff regulation adapted both to the income situation of the rural and urban poor and to the financial sustainability of the utilities.

"The principal driving forces behind this reform movement include: (a) the poor performance of the state-run electricity sector, in terms of high costs, inadequate expansion of access to electricity service for the population, and/or unreliable supply; (b) the inability of the state sector to finance needed expenditures on new investment and/or maintenance; (c) the need to remove subsidies to the sector in order to release resources for other pressing public expenditure needs; (d) the desire to raise immediate revenue for the government through the sale of assets from the sector"[52]; and (e) the advocacy by international and multilateral donors of market-oriented, financially sustainable sector reforms.

6.2 The Potential Gains from Structural Reforms

The potential gains from sector reforms are related to improvements in economic efficiency and to attraction of private capital.

Improvements in economic efficiency can emanate from three separate sources: first, linking consumer prices to the costs of production and supply, and thus eliminating subsidization of electricity supply, is expected to achieve an improved economy-wide use of resources (allocative efficiency). The extraordinary levels of untargeted electricity subsidies observed in some countries have been estimated to cause major welfare losses. However, linking prices to the cost of service may conflict with the need to subsidize rural electrification (see 6.3). "Second, the profit motive gives a stronger incentive for the efficient use of inputs, in terms of lower cost combinations and actual reductions in inputs required to produce a given output, than any incentives offered by an enterprise controlled and managed by a bureaucracy"[53] (productive efficiency). Third, introducing competition where feasible and, especially important, establishing effective regulation contributes to passing on benefits from cost reductions to consumers and thus to distributing efficiency gains among all market agents.

Huge investments are necessary to cover the increasing demand for electricity in developing countries. Thanks to privatization, a good share of the capital required may be provided by the private sector, easing the burden on governmental budgets.

Evidence on the extent to which these potential gains become effective in practice is mixed.[54] Efficiency gains can be compromised by inadequate post-reform industry structures and weak regulatory institutions. Private investments have thus far been concentrated in middle-income countries (especially in Latin America and Asia).[55] The prerequisites for private investments in the electricity sector of developing countries appear to include a growing electricity demand, stable macroeconomic and political conditions, liberalized capital flows, and legal certainty for foreign investors.

6.3 Industry Reform and Challenges for Rural Electrification

Converting electricity supply into a profitable business by allowing for cost-covering fees creates incentives for firms to invest and to seek out new markets. It is very unlikely, however, that profitability will be achieved in catering to remote and sparsely populated areas where consumers typically have very low incomes.

52 Bacon/ Besant-Jones (2002), p. 1.

53 Bacon/ Besant-Jones (2002), p. 1.

54 See Krause (2002), Ch. 5.

55 See Izaguirre (2000).

Box 3:	**Introducing Competition for the Market: Public Auctions for Concessions**
Concessions (or franchises) are one way to introduce private provision in infrastructure - and to stimulate competition *for* the market. Whenever economies of scale within an industry constitute a natural monopoly and thus preclude competition in the market, concessions grant a private company the exclusive right to use assets, to operate a defined infrastructure service, and to receive revenues from it, usually following a competitive bidding process. The competitive bidding mechanism for concession contracts should eliminate monopoly rents and hence reduce the regulatory burden.	
Source:	Bacon/ Besant-Jones (2002)

Introduction of the profit motive has positive effects on production costs and consumer orientation but may exclude commercially unattractive areas from basic infrastructure services. Experience with power-sector reform has shown that the private sector appears reluctant to expand rural access in any significant way without contractual commitments, e.g. as part of a new concession contract, or additional incentives, which may be financed via privatization proceeds.[56]

Liberalization and privatization of the electricity sector involve a need for incentive mechanisms to further the rural electrification process. Transparent and well-targeted subsidies for disadvantaged groups in rural areas need to be implemented intelligently, i.e. to be sustainable in the long run and phased out wherever possible.[57] In awarding concessions to serve rural areas, rights (and obligations) to provide services may be allocated by means of competitive auctions to the bidder demanding the lowest subsidy. Practical examples for an implementation of a procedure of this kind are the Chilean, Argentine, and South African rural electrification programs.[58]

56 See Dubash (2002), p. xi.

57 One promising approach links subsidies to performance: for example, a private concessionaire may receive public financial support after reaching established targets. This so-called “output-based” approach differs sharply from the traditional subsidization of state-owned enterprises, which failed to take performance into account. Such a results-oriented strategy may significantly improve targeting of subsidies. See Brook/ Smith (2001).

58 For a description of the Chilean case, see Jadresic (2000). For the Argentine case, see Box 6 of the present study and Covarrubias/ Reiche (2000). For the South African case, see Patterson/ Eberhard/ Suárez (2002), Box 3-3.

Cross-subsidies are a common practice in rural electrification. They raise funds by charging certain customers a price higher than the cost of service. Traditional cross-subsidies require monopolistic market structures, and without these, those paying the higher prices would defect to other suppliers, undermining the subsidy base. Hence introduction of competition may require an adaptation of subsidy schemes.

Because reforms at the macro-level and modifications of the institutional and regulatory framework lead to a market-oriented approach, modern rural electrification programs are increasingly making use of private-sector participation at the micro-level. The following chapter will detail the specific organizational and financial features of these new instruments for promoting access to basic electricity services, e.g. through off-grid PVS.

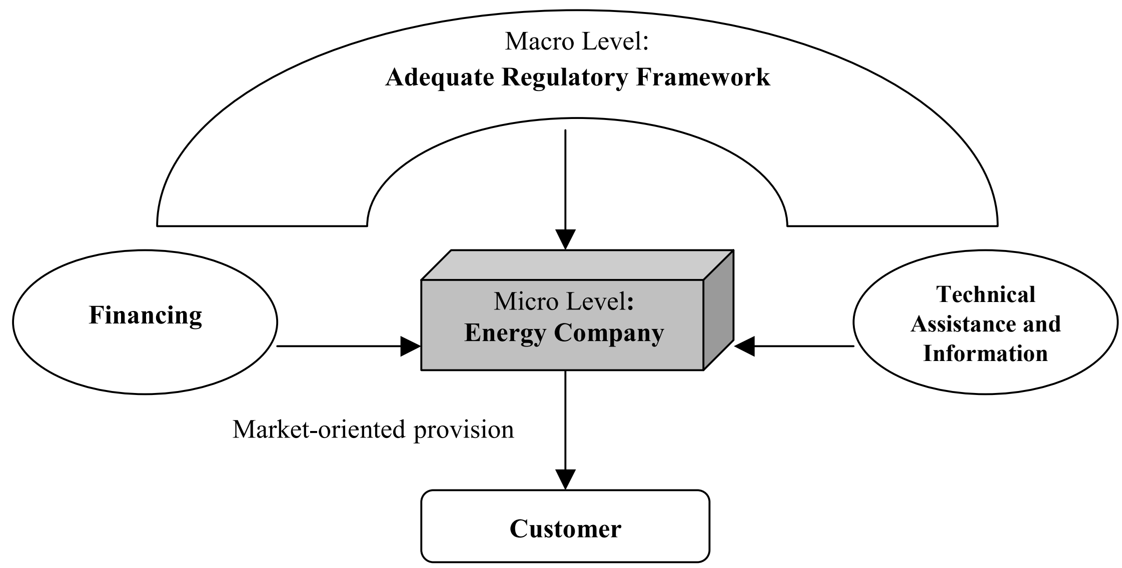
7 Approaches to Rural Electrification with Photovoltaic Systems

In the past, rural electrification with PVS often has been promoted by government or donor-driven projects.[59] Those projects usually failed to integrate adequate cost-recovery schemes and were therefore highly dependent on subsidies. Consequently, most of them turned out to be unsustainable in the long run for lack of resources.

Following privatization processes in many developing countries, rural electrification strategies are increasingly based on market-oriented principles.

59 See Reddy (2002), p. 116.

Figure 4: Creating a Conducive Environment for a Market-oriented Off-grid Electrification



Source: Adapted from Floor/ Massé/ Girdis (2001), p. 7

This implies that rural energy supply with PVS has to assure adequate returns on investment to entice private companies to enter the market. However, the areas in which off-grid PVS have a competitive advantage are often characterized by very low levels of purchasing power and education, factors tending to impede a free-market approach. Experiences have shown that without subsidies and supporting measures profit-oriented agents will not commit themselves to serve these areas.[60]

To encourage an energy company to include alternative off-grid technologies in its range of services and to direct these services to a population traditionally excluded from access to the grid, the following elements must be in place:[61]

1. a regulatory framework adapted to the needs of off-grid technologies (macro-level);
2. an adequate delivery model at the micro-level, including
   i) sustainable financing mechanisms and
   ii) information and capacity-building measures.

Thus it is necessary to create an environment conducive to market-oriented rural electrification (see Figure 4). To this end, approaches to rural electrification with PVS aim to shape and implement various institutional features at the micro- and macro-level to enhance both the sustainability and the outreach of projects.

At the macro-level, government has to develop regulatory measures and laws adapted to off-grid energy supply with renewable energies. Given this framework, the market agents at the micro-level have to decide which delivery model will be most adequate to serve rural areas with off-grid PVS. At the same time, the provision of PVS has to be accompanied by adequate financing mechanisms (often including subsidies) and information and capacity-building measures on the demand and supply side.

60 See Ch. 6.3

61 See Floor/ Massé/ Girdis (2001), p. 7.

The following two subchapters describe the institutional features at the micro- and the macro-level in more detail. As regards project management, two different delivery models, the sales and the service model, will be distinguished at the micro-level (7.1). In addition, the section includes a description of financing and technical assistance measures necessary to accompany each implementation at the micro-level. As regards regulatory framework arrangements at the macro-level (7.2), the next section will address the main areas of regulation (quality, price, outreach targets, and market entry) and present two stylized policy options: the open-market and the regulated-market framework.

7.1 Micro-level: Delivery models

At the micro-level (project management level), the energy supplier has to choose a delivery model. Two options are available for rural energy supply with PVS: The sales and the service model.[62] This classification is based on the type of the contract between the energy company and the customer.[63] Either the PV equipment is sold as a product, or the final output, electricity, is sold as a service. The two delivery models can be classified by asking the following questions about the customer-supplier relationship: Whose property is the PVS? Which party assumes the risk of spreading the initial investment costs over the lifespan of the

Box 4: Cost of Electricity Supply via Off-grid PVS

The total cost for the provision of electricity via off-grid PVS may be divided into the following **cost components** (depending on the specific delivery model and financing/ subsidization arrangement the consumers have to bear these costs integrally or only partially):

Investment cost:

- Expenditures for the purchase of the equipment;
- Expenditures for the installation (including labour, materials, transportation).

Capital cost:

- Interests on borrowed capital (typically to finance the investment costs).

Operation & Maintenance (O&M) Cost:

- Expenditures (or time costs) for corrective, routine and preventive maintenance (including labour, transportation and spare parts/ components – especially important the battery).

The **amount** of these costs varies according to national and local market conditions, duties and taxations, quality of the components, geographic conditions and specific organizational features of the delivery model. The following figures refer to the Argentine conditions and a regulated-market service model: [a]

System Size (Wp)	Investment Cost (US $)	Lifetime O&M Cost (US $)	Lifetime Total Cost (US $)	Monthly Recovery Cost (US $)
50	764	606	1,370	16.80
70	1,074	689	1,763	23.11
100	1,347	808	2,155	26.70

a Assumptions: Capital cost: 14 % pa; Lifetime of the SHS: 15 years; Battery replacement: every 3 years; charge controller replacement: every 7 years.

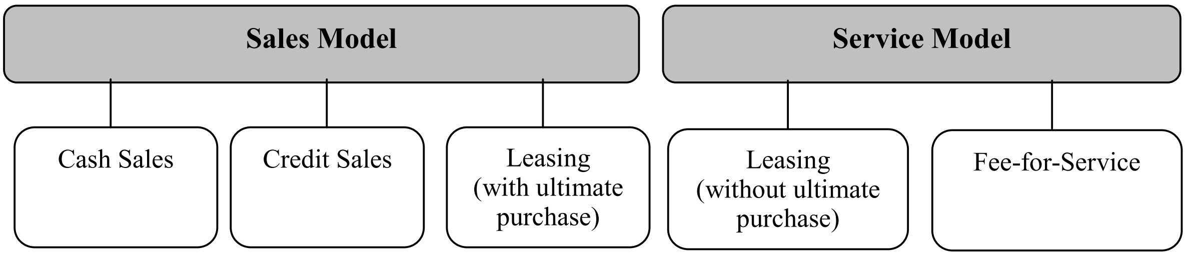
Source: Own compilation; Covarrubias/ Reiche (2000), p. 86

62 For this classification, see GTZ (2001), pp. 22-24.

system? And who is responsible for the operation & maintenance (O&M) costs of the system (see Box 4 for a classification of the cost components)?

equipment and not the additional maintenance service. Figure 5 illustrates this classification.

Figure 5: Two Delivery Models for the Energy Supply with Off-grid PVS



Source: Own illustration

Generally, there are four different types of contract:

- the equipment is sold for cash;
- the equipment is sold on credit;
- the equipment is leased against a fee (with or without ultimate purchase);
- the integral energy service (leasing of the equipment and provision of maintenance service) is sold for a fee.

The first two forms are sales model contracts, whereas the forth form represents the service model. The leasing[64] arrangement could be assigned to the sales model if it provides for an ultimate property transfer via purchase. Otherwise, it might be assigned to the service model, even though service includes just the leasing of the equipment and not the additional maintenance service. Figure 5 illustrates this classification.

Regardless of the concrete delivery model chosen, there are some basic functions that have to be met during any project management process:

Aside from providing for i) sustainable financing and ii) information and capacity-building (see above), three basic technical functions have to be met in order to provide energy: iii) marketing of the PVS (choice of an actuation area and establishment of contacts to consumers interested in a PVS); iv) dimensioning and installation of the PVS; v) maintenance of the PVS (see Box 5 for a classification of maintenance categories).

Since performance on these functions will affect the technical and financial sustainability of the delivery approach concerned, they will be used in Chapter 11 to describe and assess the Brazilian delivery models investigated.

The following sections describe the sales (7.1.1) and the service model (7.1.2) in more detail, paying special attention to the financing aspect and the respective options that are available. The importance of information and capacity building measures is then looked into (7.1.3).

63 It is important to note that the customer may be a private individual as well as a public institution. Likewise, the supplier may be a private or a public company.

64 Leasing is defined as a special form of renting of either capital or consumption goods. Usually, a leasing company buys the product, maintains its property, and rents it out to users. Since the good in question remains the property of the leasing company, special arrangements for maintenance have to be made. After termination of the leasing contract, the user typically has the option to purchase the product. See Gabler (1997).

Box 5: Maintenance Categories for Off-grid PVS
In order to assure the quality of the energy service and the continuous and reliable functioning of PVS, some maintenance activities are necessary. It is useful to distinguish between the following maintenance categories: *Corrective maintenance* is necessary when a component or function of the PVS fails and this failure is not attributable to normal wear, i.e. the failure occurs before the end of the average product life of the relevant component. In this case the component needs to be repaired or substituted. More expensive components, like the solar panel, the charge controller and the battery typically are covered by a manufacturers' guarantee during a part of their average life. Corrective maintenance typically needs to be provided by qualified technicians. *Routine maintenance* refers to the ordinary replacement of components that have reached the end of their product life (e.g. periodical substitution of the battery). Typically, the substitution of the lamps and the electronic ballast is counted among routine maintenance (though their product life may be very short depending on their quality). Normally, routine maintenance is provided by trained local persons or by the users themselves. *Preventive maintenance* refers to actions taken before a failure occurs in order to maximise the availability of the system and the product life of components. These actions may be taken by the users (cleaning of the panel, fill up distilled water in the battery, if this applies etc.) or by a trained local person (control of contacts, sockets etc.). Often preventive maintenance confounds with what might be called *correct operation*, i.e. not to alter the PVS installations and not to overcharge the capacity of the system.
Source: Santos (2002)

7.1.1 The Sales Model

Under the sales model, marketing is effected via a network of provider firms which sell the PVS directly to rural households. After the sale, the PVS remains the property of the private household, which is responsible for its maintenance (costs) and, in cases of credit-based sale, for the regular payment of debt service. This means that the sales contract usually includes only a limited manufacturer's guarantee but no complete maintenance service.[65] The maintenance of the PVS therefore has to be arranged for by the customer himself or on the basis of an extra service contract. This service may be offered by the PVS dealer or by a third party such as a trained local person or a special service company. Thus the user of the PVS not only has to cope with the investment costs, he also has to bear the O&M costs during the system's lifespan. These O&M costs can take two forms: i) irregular payments whenever an acute failure occurs or replacement of a component becomes necessary (e.g. the battery or a lamp), or ii) regular fee payments when the maintenance service is contracted out to a service company.

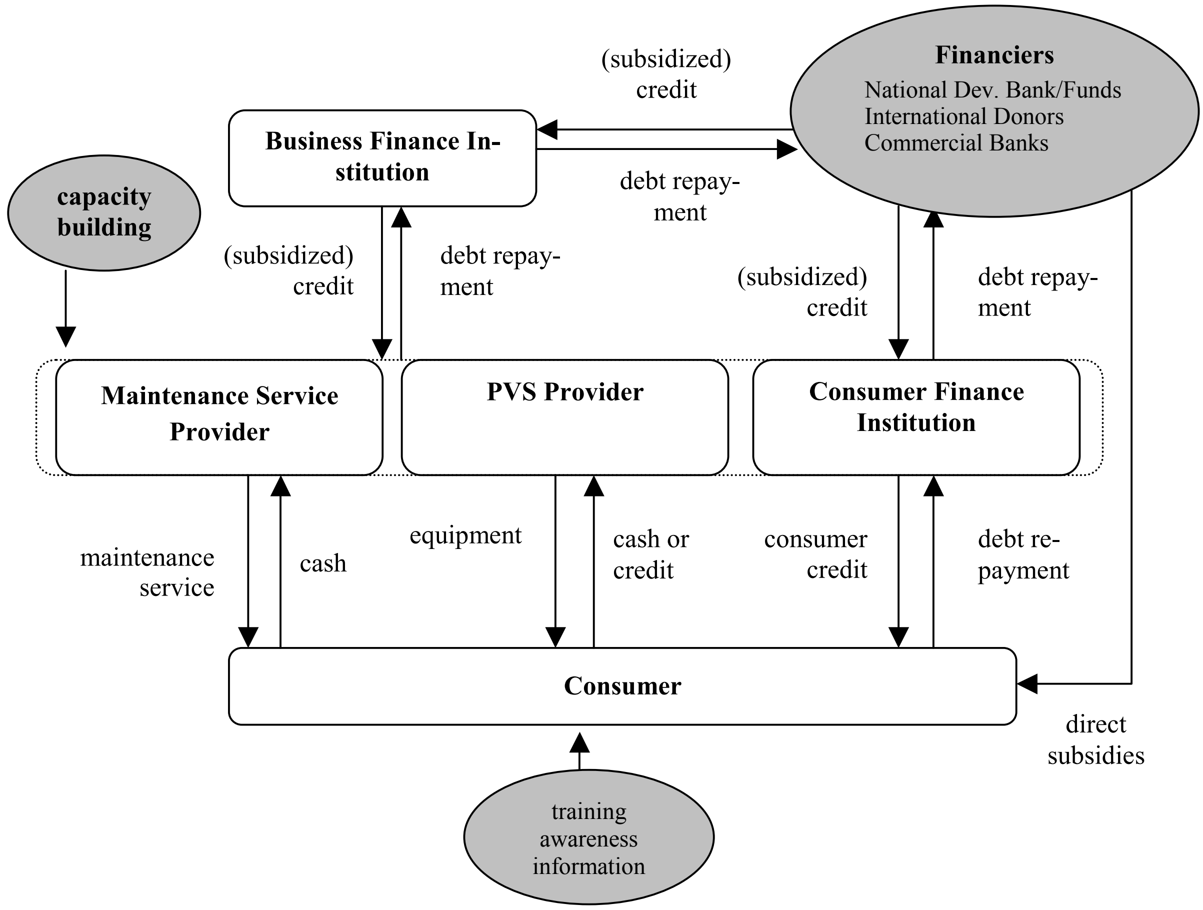
Consequently, under the sales model the customer is obliged to bear any risk involved with the operation of and financing of the investment and O&M costs of the PVS.[66] Figure 6 illustrates the agents involved, the relations between them, and possible supporting activities like financing and capacity-building and information measures under the sales model.[67]

65 A guarantee is usually granted by the producer for a limited period after the sale. It guarantees a right to replacement in case of component failure, presupposing the failure is not due to user misuse - whereas maintenance service is a specialized, local service which is independent of the sales contract and includes basically provision of skilled labor and specific information that is necessary to identify and repair any kind of technical failure.

66 In the case of a credit purchase, though, some risk related to the investment costs could be transferred to the credit supplier. The product guarantee also relieves the user for a limited time of the risk of system malfunction due to low product quality.

67 The relevance of technical assistance and information will be explained in more detail in Chapter 7.1.3.

Figure 6: The Sales Delivery Model



Source: Own illustration

7.1.1.1 Demand-side Financing

The sales model is based on the assumption that potential users are able and willing to pay for a PVS. However, in rural and sparsely populated regions of developing countries – where PVS is a rational alternative for energy supply – the majority of the population typically have very low and volatile incomes.[68] Thus most rural households are not able to finance the initial **investment costs** in a single cash payment (see Box 4 for an illustration of amount of investment costs).

Credit financing can make PVS more affordable for the rural population. Studies have shown that consumers in developing countries are often willing to pay a substantial amount for reliable energy supply.[69] Estimates suggest that the average rural household spends between US $ 3 to 10 per month on traditional energies like candles, kerosene, and liquefied petroleum gas.[70] With a PVS installed, this expenditure can be saved and used for a credit-based purchase of a PVS.

Consequently, the success of the sales model will depend to a large extent on the availability of a **credit provision** adapted to the potential customer group of low-income households. Although financing mechanisms can generally be based on

68 See pyramid model, Ch. 5.

69 See Martinot/ Cabraal/ Mathur (2001).

70 See Terberger/ Schubert/ Gocht (2002), p. 2.

market conditions, commercial banks are not the adequate institutions to provide financial services oriented to this target group. High transaction and administrative costs involved with low credit volumes as well as the higher perceived risk of the low-income group induce these banks to concentrate on lending to middle- to high-income groups in urban areas. Thus the task of target-group-oriented lending may instead be assumed directly by local PVS dealers, or indirectly by rural micro-finance institutions.

A substantial share of the low-income population may not be reached by credit financing at market conditions. In these cases, **subsidies** have to be looked to as a means of increasing the outreach of the off-grid energy supply with PV technology. Indirect subsidies can take the form of soft loans (e.g. by development banks or revolving fund arrangements provided by local micro-finance institutions). Direct subsidies can be provided to lower the price of the PVS for customers, or PVS may even be provided in the form of an outright grant.[71]

There are also other forms of financing for PVS investment costs under the sales model (see Figure 5). One option is a combination of a credit and cash sale. Another alternative is hire-purchase, a form of leasing with an ultimate purchase agreement.

Besides the investment cost, the consumers also have to cope with irregular payments for **O&M costs**. Financing them is usually seen as more complicated.[72] Whereas the PVS can serve as collateral for financing the investment costs, O&M costs represent additional expenditures that are not covered by collateral. O&M costs should therefore generally be covered by the consumers. However, it is important to determine whether this will be affordable over the medium and long term. Limiting the perspective to the financing of the investment costs may have serious consequences for the widespread introduction and sustainability of off-grid PV energy supply based on the sales model. Ignoring the O&M costs, especially the additional costs due to unexpected replacements of components, has often led to difficulties with the implementation of PVS programs. A lack of ability or willingness to pay – due e.g. to permanent failures – can contribute to the collapse of credit schemes.[73]

In sum, under the sales model the combination of high initial PVS investment costs (and irregular O&M costs) and low purchasing power on the demand side represent a major barrier to the expansion of the market for off-grid PVS. The outreach and sustainability of this delivery model thus depend to a high degree on the provision of adequate consumer finance mechanisms.[74]

7.1.1.2 Supply-side Financing

Supply-side financing under the sales model is almost as important as demand-side financing, because dealers have to finance the investment costs of PVS before sales begin. Small and under-capitalized local firms in particular often have limited access to business finance. Due to low expectations of returns and high risk perceptions, there are hardly any commercial credits available.

Special subsidized financing mechanism may therefore be necessary to enable the development of small local dealers: soft loans help to mitigate

71 This implies that the user has only to finance the O&M costs but not the investment costs. Experiences have shown, though, that a high degree of direct subsidies often lead to a lack of user ownership: in consequence, often either systems were sold or not operated and maintained adequately.

72 The payments for O&M costs may be regular, in case the user has contracted out the maintenance to a special service company against a regular fee.

73 See Ch. 11.2 for an example with this kind of difficulties. See also GTZ (2001), p. 13-14, and the project examples of Tunisia, Bolivia, Morocco, and Lesotho (Volume II: Case Studies).

74 Because of the high initial investment barrier, pilot projects based on the sales model often have in the end only reached a small share of the rural population with higher incomes. See pyramid model, Ch. 5.

the investment risk and also to increase the attractiveness of PVS sales activities in rural areas. Direct supply-side subsidies have the same effects and hence enable small and medium-sized dealers to refinance their investments and expand PVS sales service. It is very difficult, however, to monitor the targeting of direct supply subsidies. The dealer will have incentives to sell the subsidized PVS not to the target group but to wealthier households that can afford to pay the regular market price.

7.1.2 The Service Model

An energy company which opts for the service model offers solar electricity as a service to rural consumers. The PVS remains the property of the energy company, which means that it does not sell the PVS, but supplies the energy service for a regularly collected fee.[75] Usually, the fee-based contract includes the installation of the PV equipment as well as necessary maintenance services. The energy service may be provided by a regulated concession holder (an existing utility or a competitively selected private firm), an unregulated open-market provider, or a community-based provider.

7.1.2.1 Demand-side Financing

Under the service model, the consumer does not have to directly finance the initial investment and the O&M costs. This responsibility is in this case transferred to the energy service company. However, the energy service company refinances itself by charging a fee, in this way passing on the costs (wholly or in part) to the consumer.

In principle, if the PVS does not work, due e.g. to lack of maintenance by the provider, the consumer can simply stop paying the monthly fee and switch back to candles or other traditional energy sources. He loses the convenience of clean electricity but does not incur a financial risk.

In general, it is not recommended that consumer credits be granted under the service model because the service fee is a recurrent expenditure. The regular fee payment for the solar energy supply should therefore be financed from the costs saved, i.e. what a rural household would normally have to spend on other conventional energy sources like candles, kerosene, and liquefied petroleum gas. Studies have shown that such a tariff – based on the estimated opportunity cost of rural households – averages between US $ 3-10 per month.[76] In many developing countries, this calculation is used to set an officially regulated maximum tariff for poor households.[77]

However, if the tariff is above this affordability limit for a rural household, direct subsidies could be given to the user to fill the gap. But as the delivery of direct subsidies to rural areas with low population density involves high transaction costs and organizational problems, it is easier to provide subsidies on the supply side in order to lower the tariff to an acceptable limit.[78] This possibility will be discussed below.

7.1.2.2 Supply-side Financing

Under the service model, the financing of the high initial cost of the PVS is transferred from the customer to the energy service company. This means that the company has to assume the risk of spreading the costs over the lifespan of the system. In other words, under the service model financing by

75 Usually, the fees are collected monthly. Breaking down the payments into small amounts is very important since it facilitates access for low-income groups and avoids any need for financing measures on the demand side.

76 See Terberger/ Schubert /Gocht (2002), p. 2.

77 Application of the social maximum tariff is usually based on the amount of energy consumed. E.g. all households consuming less than 30 kWh/month are classified as low-income and thus benefit from the subsidized tariff. See Ch. 9.3 for the Brazilian case.

78 Regarding the issue of subsidization, see Albouy/ Nadifi (2000), pp. 3-6.

the energy service company plays a major role in guaranteeing a sustainable provision of solar energy to rural areas.

Business financing at market conditions is usually easier to obtain than consumer credit. This is due to the greater credit volume, lower risk perception, the availability of securities, etc. Thus if the energy service company has a sound business plan and the necessary creditworthiness, it can obtain the necessary capital from a commercial bank or via other financing mechanisms available in the capital market.

Still, since providers of PV energy for rural areas operate in an innovative branch of industry and serve markets with low purchasing power, they are seen a having a higher business risk, and this may call for **subsidies**. In addition to market financing, special subsidized credit lines would therefore be one means of guaranteeing an adequate financing of energy service companies and setting incentives for an expansion of the supply of solar energy services to rural areas.

Subsidizing the supply side may also become necessary because of the low incomes of potential customers. This factor inhibits the economic sustainability of the fee-for-service arrangement for energy supply with PVS to rural regions. In most cases, the socially acceptable tariff of US $ 3-10 per month is below the full cost-recovering tariff of around US $ 17-26 per month. When the regulated maximum energy tariff is below the full cost recovery tariff, energy provision with PVS to rural areas is not an economically viable business for the energy company. It is thus necessary to subsidize the service company as a means of closing the gap between the social tariff and the full cost-recovering tariff. In general, it is possible either to grant (conditioned) **direct subsidies** to the provider or to offer **indirect subsidies** in form of the above-mentioned special credit lines.

If the energy service company serves a sufficient amount of wealthier consumers, **cross-subsidies** may be an alternative. Low-income off-grid consumers can be financed through higher tariffs in regions that are better off.[79] For smaller companies whose operations are limited to a low-income region, these cross-subsidization mechanisms can be replaced by redistribution mechanisms administered at the federal or state level.

Other possibilities to lower costs of the PVS include **tax rebates** or **reduction of import duties** on PVS components.[80]

Figure 7 illustrates the agents involved, the relations between them, and possible supporting activities like financing and capacity-building and information measures under the service model.

7.1.3 Capacity-building and Information

Apart from financing mechanisms, supporting measures geared to training of and provision of information to customers and suppliers are important to ensure that the provision of PV energy to rural areas has the desired outreach and sustainability.

Technical Instruction for Users

The technical operation of the PV equipment is an important variable that determines its lifespan costs and has a major influence on customer satisfaction. Although PVS is a reliable technology, it is not maintenance-free.[81] The lifespan of the battery, the charge controller, the ballast, and the fluorescent lamps represents the greatest challenge.[82] The average lifespan of individual components depends crucially on proper handling and

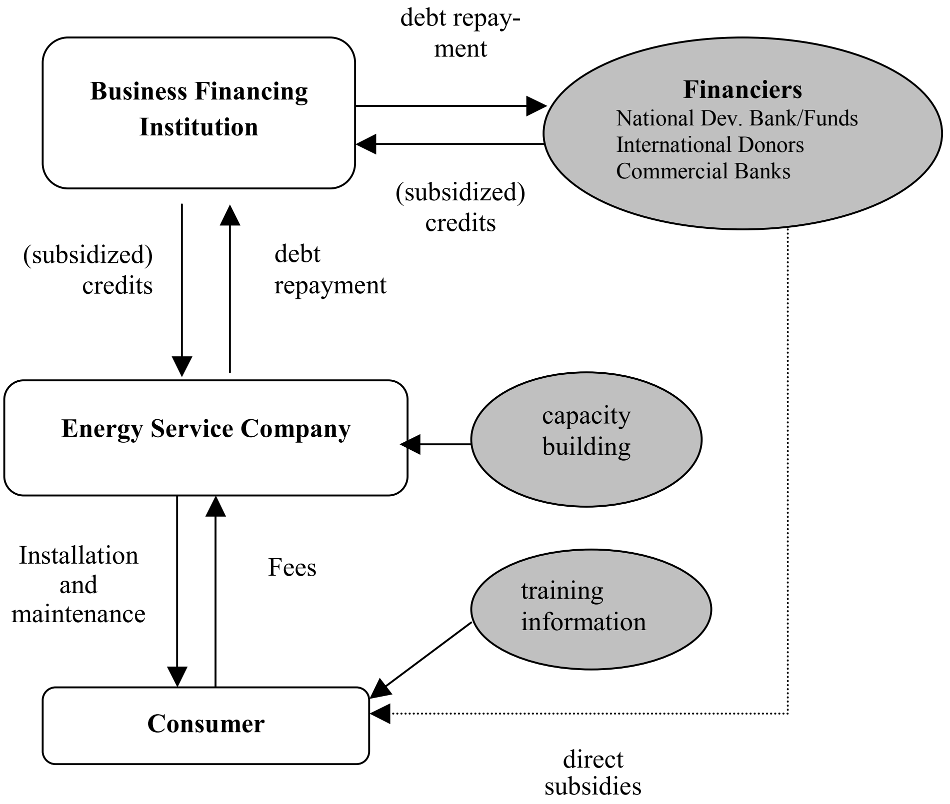
79 The subject of cross-subsidies will be further addressed in Chapter 7.2.

80 This measure also applies for the sales model.

81 See also Box 5.

82 For technical details of the PVS, see Box 1.

Figure 7: The Service Model



Source: Own illustration

maintenance of the components as well as on their type and quality. Customer willingness to pay is crucial for the financial sustainability of a market-oriented provision of PV energy. Customer satisfaction is therefore not only an objective in itself but also a basic condition for the financial sustainability of the overall PVS market – it determines willingness to pay.

Proper handling and maintenance are especially important if the full potential lifespan of the battery is to be realized. The risk of early failure can be greatly reduced by providing adequate technical instruction.

The durability of the ballast, the fluorescent lamps, and the battery control unit is less a question of proper handling than of component quality. Inadequate quality standards and low user purchasing power often mean installation of cheap products at the expense of durability. Thus it is important to inform the customer about the trade-off between the price of a product and its durability. This is especially true under the sales model, where the customer is responsible for purchasing the components.

It is crucial that users are informed about limited generation capacity before they sign a sales or service contract. Marketing campaigns tend to concentrate on the advantages of the PVS and thus often awaken false expectations about the overall system's peak capacity. The consequence may be system overload or misuse, resulting in failure and thus increased costs. Later, the user may have little incentive to meet payments for debt service or the fee, respectively. Hence adequate system dimensioning and consumer information should be an integral element of every project concept.

Technical Assistance to the Supplier

Energy companies engaged in rural electrification must have personnel trained to manage projects designed to provide maintenance service and training for users. Successful project management is an important factor in minimizing O&M costs and thus increasing the technical and financial sustainability of PVS provision.

One specific problem is the lack of trained persons in rural areas. Availability of local technicians can be increased by providing enhanced training in renewable energies in mechanical, electrical, and hydraulic engineering at local technical schools and universities. Business development services contribute to improving the management and administration skills of smaller PVS providers. Staff training may include customer relations, access to business finance, technology choice, project management, etc.

Information about Technology and Markets

Private investors are often reluctant to invest in off-grid technologies because they lack information about market size, locational characteristics, and O&M costs in dispersed, rural regions. Market surveys and feasibility studies provide this kind of information and thus may stimulate investments.

7.2 Macro-level: Regulation of the Market

The decision taken on delivery model at the micro-level is highly dependent on the regulatory framework at the macro-level. Recent global trends in the energy sector toward market-oriented supply have been outlined in Chapter 6. These privatization and liberalization processes are directed and influenced by regulatory policy. In what follows, two stylized policy options for a market-oriented provision of off-grid PVS will be distinguished: the open-market framework and the regulated-market framework.

These two models will be characterized with reference to four areas of regulatory policy action which are especially relevant for the case of rural electrification with off-grid PVS: (1) quality standards, (2) price regulation, (3) outreach targets, and (4) market entry.

Regulation of market entry will serve as the principal classification criterion. If the market is open to all potential providers, the regulatory design is defined as an open-market framework. If market entry is restricted, the design is characterized as a regulated-market framework**.** The open-market framework rules out any type of regulatory intervention in the market, apart from quality standards. The regulated-market framework can involve other regulatory measures like outreach targets, price regulation, and quality standards.

7.2.1 Principal Regulatory Functions

The four relevant functions of regulation will be described in more detail before they are used to classify the two frameworks mentioned above.

Regulation of Quality Standards

Quality standards comprise two areas: standards for PVS components (and installation) and standards for the quality of the service provided by means of PVS:

In recent years, a wide range of international quality standards have been developed for PVS components, and major efforts have been undertaken to harmonize them.[83] The lessons learned point in particular to battery quality as a factor crucial to reducing environmental damage and O&M costs. High-quality batteries and an elaborate disposal and recycling mechanism should be an integral element of PVS quality regulation. Nevertheless, there is a certain trade-off between more expensive solar batteries with a long product life but

83 For a summary of international PVS quality standards and institutions, see GTZ (2000).

usually limited availability in rural areas and cheaper automotive batteries with a shorter life but higher availability.

Standards for the service quality relate mainly to supply interruption frequencies and durations. Practical examples of quality standards for PVS service provision are very rare (in contrast to grid service provision). Minimum standards for service quality aim to protect the consumer and are especially important in regulatory arrangements that provide for a service obligation of the supplier (typically a concession holder in a regulated-market framework – see below) to prevent the service supplier from shirking his obligation to deliver good quality. Because the energy is produced decentrally under varying local conditions, and standards for the equipment in use also vary considerably, standards for service quality are hard to define and even harder to monitor and enforce.

Regulation concerning these issues need not necessarily contain the same specifications for every region. It has proven essential to target regulation to regional socioeconomic or technological conditions: it is for example useful to distinguish between urban and rural areas in looking at service quality.[84]

Price Regulation

Regulation of consumer prices (tariffs) is common in the electricity sector, although such regulation is supposed to give rise to considerable market distortions.[85] However, price caps and cross-subsidies may be necessary to foster the outreach of rural energy supply.[86]

Regulation of electricity prices is one way of using cross-subsidization to cover the high costs of rural electrification. This is only possible when one single provider (e.g. a concessionaire, see below) covers a large and heterogeneous territory which includes both urban, wealthier, areas with high electricity density and rural areas with low electricity density and, usually, a low-income population. Since average costs of electricity supply decrease with increasing electricity density, electricity prices in low-density areas would have to be very high, whereas prices in the urban areas could be lower.[87] It is, though, possible to set the regulated price somewhere between the full cost-recovery price of two such areas. Additional profits earned in urban areas can in this way be used to subsidize rural electrification. Seen in this way, price regulation is an instrument of interregional redistribution.

However, price regulation geared to cross-subsidies is used not only to make rural electrification profitable but also to set electricity prices at a socially acceptable level and thus to ensure that low-income households have access to electricity. Seen in this way, price regulation is an instrument of redistribution between income groups.

Regulation of Outreach Targets

Regulation of outreach targets is another way to foster electricity supply in rural areas. Outreach targets are quantitative targets for the provision of energy within a defined timeframe; they are as a rule fixed between the state and an energy provider. Thus they are only possible within the framework of a concession contract.

Outreach targets usually force the concessionaire to expand the electricity supply to areas which are not economically attractive to the company (e.g. poor rural areas with low electricity density and thus high average costs). This means that the energy company is likely to incur constant losses in

84 See Ramanathan / Mishra (2000), p. 3.

85 See Chapter 6.

86 Price caps are maximum prices that final consumers can be charged.

87 The reason for this relation is that electricity supply involves high fixed costs (like transmission lines, power stations, maintenance capacities, etc.) that in areas of high electricity density can be spread over a large number of clients - whereas in low density areas every client has to pay a much higher share of the fixed costs.

Box 6:	**The Argentine Regulation Concerning Outreach Targets**
As part of the Argentine electricity sector reform regional concessions were awarded, which contain the obligation to universally electrify the included provinces according to consumer demands. For every province an exclusive concession was awarded for a 15-year-period. The concession is auctioned to the bidder, who requires the least subsidies to reach the fixed goals. It includes explicitly RET as a means for rural electricity supply. Nevertheless the Argentine case is a special one, as the supply density is already quite high.	
Source:	Martinot/ Cabraal/ Mathur (2001), pp. 3-9

fulfilling its contractual obligations. Regulation of outreach targets therefore has to go hand in hand with a price regulation that allows for cross-subsidization or other forms of direct and indirect subsidies (e.g. grants or special credit lines financed from a sectoral fund or the state budget).

Regulation of Market Entry

Market entry can either be open to all potential competitors or it can be limited to holders of a public concession.

7.2.2 Open-market Framework

The open-market framework allows free entry to the market. This means that all market agents that are able to provide off-grid PVS in a commercially sustainable manner can choose to serve any region in a national territory. In an open-market-framework rural electrification with off-grid PVS is mainly determined by market forces and competition in the market. However, this has to be distinguished from a wholly unregulated market framework, since in the former case the state has the option of intervening to guarantee certain quality standards for the electricity service with PVS.

The strong emphasis on market forces under this framework limits the role of the government to that of a facilitator who provides market-conforming incentives to stimulate the commercial dissemination of PVS. Thus policy instruments like financing and supporting measures play a much more important role here than intervention based on regulations. Under this approach regulatory measures are limited to the definition and enforcement of quality standards.

7.2.3 Regulated-market Framework

The main objective of the regulated-market framework is usually not a decentralized market development for PVS but a countrywide universalization of access to energy based on political and welfare aspects. Under the regulated-market framework entry to the energy market is regulated. The government grants exclusive concessions to existing energy utilities or new, competitively selected private firms which authorize these companies to provide (renewable) energy services in a specific region.

Thus under the regulated-market framework the government can govern the dissemination of PVS by including outreach targets in the concessions it grants. It can also use regulatory measures (including cross-subsidies) to influence electricity prices and service quality.

Usually the concessions include exclusivity, which inhibits competition in the market.[88] On the other hand, an adequate degree of competition can be ensured if the bidding process for concessionaires is organized in an open and transparent way (*competition for the market*).[89] This is the case when the concession is granted to the energy service company that offers the bid with the lowest subsidy element. For commercial provision of

88 See Chapter 6.

89 See Box 3.

PVS under this framework, the fee-for-service arrangement is the most common delivery model.

7.2.4 Integrating Photovoltaic Systems in the Regulated-market Framework

Integrating technological innovations within rural electrification strategies poses a considerable challenge to many developing countries. A new technology like off-grid PVS initially operates in an open-market framework until rules are established to govern its application. It is a demanding task to design tariff policy, quality standards, and service principles which do justice to the technological peculiarities of alternative sources of electric energy and realize their full potential to extend basic service provision. If a regulatory framework distorts the competition situation in terms of costs and operation, e.g. by using poorly designed subsidies for grid and off-grid electricity, the result will be inefficient service provision.

In the past a variety of agents have implemented off-grid PVS projects within a single country, often experimenting with different delivery models, equipment, or maintenance schemes. If a government elects to make off-grid PVS part of its rural electrification policy, with the objective of setting a unified framework for their targeted dissemination, it has to deal with agents that have otherwise not been compelled to comply with a regulatory framework.

A shift to the regulated-market framework usually restricts participation in the market to holders of a public concession. NGOs and private-sector actors would thus be excluded unless they obtain permits which authorize their continued operation or articulation schemes are found that allow these "non-concessionaires" to act as subcontractors of concessionaires. In addition, financial and technical assistance may both be needed to ensure a level playing field for established agents in the new environment.

8 Electricity Supply and Rural Development[90]

We can distinguish two main effects of energy services on rural development: the direct effect on basic needs and activities (safe drinking water, good-quality and healthy lighting, cooking etc.) and the indirect effect on income generation and employment (through the use of motors etc. for productive activities). The most common implementation of PV technology for rural energy supply are SHS. Since SHS are not suited for the operation of appliances that require higher loads (e.g. electric sewing machines), their potential benefits stem mainly from the direct effect.

8.1 Relation between Energy Services and Rural Development

Electrification is seen as closely related to the social and economic development of rural areas. Consequently, the common objectives of rural electrification programs include, among others:[91]

- promotion of agricultural, industrial, and commercial development of rural areas, and thus income generation;
- improvement of quality of life (higher-quality lighting and use of electric appliances);
- reduction of rural poverty;
- reduction of migration from rural to urban areas;
- redressing urban bias.

90 The environmental dimension of development is not addressed in this chapter. See Chapter 3 for a discussion of this issue and of the benefits from using RET.

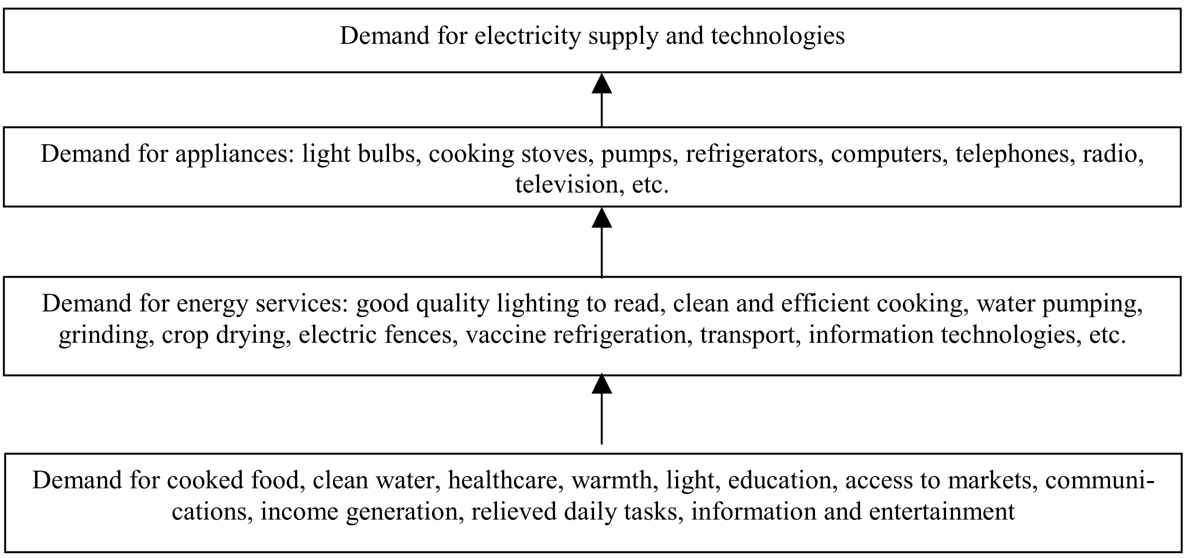
91 See Campen/ Guidi/ Best (2000), Annex 3.

However, there is some controversy as to whether rural electrification actually contributes substantially to meeting these objectives. In spite of the widespread assumption of a close relationship between electrification and rural development, there is not much sound empirical evidence that supports this hypothesis. This is especially true concerning the causal relationship between electricity supply and rural development. It appears that in general "the success of rural electrification follows and supports socio-economic development, rather that the other way around."[92] Apart from this, various studies have found that higher-income groups benefit more from rural electrification programs than low-income groups.[93]

To understand the potential impacts of electricity, it is useful to broaden the perspective from the supply of electricity to the demand for rural energy services and to conceive the demand for electricity as a derived demand (see Figure 8). Derived demand means here that demand for energy is not seen as a means in itself but as a necessary input for meeting needs and engaging in activities like cooking, lighting, safe drinking water, transportation, irrigation, refrigeration, crop processing, wood processing, use of communication technologies, etc. Not every energy-supply technology is suited to support each of these end-use activities. Feasible applications of the PV technology are discussed below.

What is the impact of the supply of modern energy technologies on development? Using the Human Development Index (HDI) as a measure for development, we can distinguish two possible positive effects of energy services on the HDI:[94] a direct and an indirect effect. The direct effect relates mainly to access to safe and clean cooking, safe drinking water, safe and clean lighting, food preservation, and entertainment. This direct effect is largely restricted to the household, though it may also extend to the place of work or to municipal services like schools or health clinics. The

Figure 8: Electricity as a Derived Demand



Source: Adapted from Wilkins (2002), p. 17

92 Campen/ Guidi/ Best (2000), p. 4.

93 See Cecelski (2000), p. 9.

indirect effect relates to an improvement of employment and income-generation situations through the use of motors and process heat, but also through lighting and communication technologies. The use of appliances operated on the basis of available modern energy services leads to an increase in productivity, which means that households gain extra time for additional activities and leisure. The positive correlation between energy consumption and HDI holds not only theoretically but empirically as well. Improvements on the HDI are especially high for small increases in energy consumption that start out at a very low level of energy consumption.[95]

It should be stressed, though, that the majority of benefits from access to modern energy services depend on a set of additional factors like availability of other infrastructure services (piped water, roads, telecommunication, educational and health facilities), a skilled labor force, and access to markets for products and services that may be produced thanks to modern energy technologies.

8.2 Specific Comments on Photovoltaic Technology

Since off-grid PVS are suited for providing only small amounts of energy, their record has to be examined apart from e.g. grid extension or small-scale hydropower,[96] which would offer service of significantly higher capacity (see Table A1 for a specification of typical capacities of SHS and suitable appliances). The development effects of PVS will be discussed in relation to the type of consumer involved, i.e. the individual household and the community level. Moreover, the influence of electricity supply on gender issues will be discussed briefly.[97]

Table 2: Individual Use of PV Technology and Related Benefits

Solar Home Systems	Lighting	Less health risks Improvement of quality of life Improvement/access to income generating activities Improved education possibilities
	Small Domestic Appliances (e.g. Blenders)	Improvement of quality of life Improvement/Access to income generating activities
	Radio/TV; Phone	Access to information Social inclusion Participation
Electric Fences		Improved keeping of animal Improvement/access to income generating activities
Water Pumps (drinking water)		Less health risks Improvement of quality of life

Source: Own illustration

At the **individual level** (see Table 2), the by far most common implementation of PV technology is SHS,[98] with their typical applications for lighting, radio and TV, small domestic appliances (e.g.

94 The following comments are based on Reddy (2002), pp. 115-121.

95 Reddy (2002), p. 119, infers from this that the direct effect is especially important for development. Another important current in the literature argues, by contrast, that the effect of electricity on basic needs is small and highlights the role of energy services for supporting economic growth and income generation. See Albouy / Nadifi (2000), p. 3.

96 See also Ch. 4.

97 See Campen/ Guidi/ Best (2000) for a thorough analysis of the impacts of PVS on rural development.

98 See Campen/ Guidi/ Best (2000), pp. 14-16.

blenders; typically *not*: electric stoves for cooking, electric sewing machines, irons, refrigerators),[99] and possibly mobile telephones. Other less common applications of PV technology at the individual level are water pumps and electric fencing for livestock. Unlike systems for electric fencing, SHS are not designed explicitly for productive activities. As an energy supply system for a small shop, bar, or workshop, though, SHS may be quite suitable for use for income generation.

Lighting and other domestic appliances not only improve the quality of life of the rural population, they also increase security and open up educational opportunities. If e.g. the commonly used kerosene lamps are replaced by electric bulbs, harmful smoke, and hence the risk of respiratory illnesses, is reduced. Moreover, high-quality lamps can avoid eye damage due to bad lighting. Kerosene lamps also involve a danger of uncontrolled fire, which constitutes a substantial risk for household members. Education can be enhanced by electric lighting, since good lighting makes it possible to study during the evening.[100] Water pumps that ensure clean drinking water reduce health risks and provide relief for everyday tasks as well.

Apart from health and quality-of-life-related effects, lighting also creates new possibilities for income generation, since adequate lighting makes it possible to shift household work to the evening hours, which provides people with more time for productive activities. Similarly, radio, TV, and telephones can create income e.g. by providing information about existing markets and new products. Domestic appliances foster the effectiveness of handcrafts and can support productive employment. Electric fences contribute to increased productivity in animal husbandry and create additional income.

The empirical investigation in Brazil at the individual level was limited to the development impacts of SHS (see Chapter 12).

At the **community level** (see Table 3**),** systems with higher capacity are typically installed to provide additional electricity and allow for appliances that require a higher load, like computers, refrigerators, video cassette recorders (VCR), or water pumps for irrigation. These appliances are usually used in a productive way or for social purposes (see Table 3). For example, a PVS-powered irrigation system constitutes an important advance for a communities' agricultural activities. At the social level, electricity is most commonly used in community centers, schools, and local health clinics. Computers, radio, TV, or VCRs are important means of education and access to information. In local health clinics, the most important advance is constant and good quality lighting as well as the possibility to refrigerate vaccines and other medicines as a means of improving rural health services.

Table 3: Community Use of PV Technology and Related Benefits

Computer VCR/TV/Radio Phone	Improvement of educational possibilities Access to information Participation
Irrigation/ Water Supply for Humans and Animals	Improvement/access to income generating activities Improvement of quality of life
Refrigeration Lighting	Improvement of health services Improvement of food storing Improvement/access to income generating activities

Source: Own illustration

99 Which domestic appliances can be used depends to a large extent on the size of the PVS as well as on household income. See Table A 1.

100 See Wilkins (2002), p. 28.

The community-level empirical investigation in Brazil was limited to an analysis of school systems and PVS for community centers, i.e. it did not consider systems explicitly designed for income-generating activities (e.g. irrigation systems) (see Chapter 12).

Looking at **gender issues**, experiences indicate that rural electrification in particular not only eases women's work directly but at the same time also improves the conditions under which women do their daily work.[101] This is underpinned by the fact that electricity is predominantly used for lighting and to operate other domestic appliances. Thus women and their health status can benefit greatly from rural electrification. Electricity makes it possible to do household work faster and more easily, and the time won and labor saved can be used for productive activities or personal interests, enhanced social participation, and human capital formation through education.[102]

101 See Reddy (2000), p. 43.

102 For a comprehensive examination of the gender-electricity relation, see Cecelski (2000).

III. The Brazilian Case Study

9 Legal, Economic, and Political Conditions for Rural Electrification with Photovoltaic Systems in Brazil

The regulatory framework of the Brazilian energy sector is currently undergoing profound change. A first set of structural reforms was conducted in the mid-1990s; its aim was to introduce competition and attract private capital along the lines laid out in Chapter 6. The service provided by the privatized concessionaires did not meet important social policy objectives, such as acceleration of rural electrification indices, and thus pointed to some drawbacks of the reform process.

The Brazilian energy crisis of 2000 highlighted the failure of the new regulatory framework and triggered a second wave of sectoral reforms. Aside from diversifying the energy matrix and promoting investment in thermal power generation, it is now recognized that extension of electricity services to all Brazilians calls for public policy action, and this now ranks among the priorities of reform.

If properly implemented, the new initiative for the universalization of electricity service will fundamentally alter the rules for rural electrification. Following the privatization process of the mid-1990s, private initiative did not replace costly public funding of rural electrification. Under new legislation, regulation imposes binding target areas and schedules for concessionaires to realize universal access to electric energy.

A fraction of the potential future consumers display characteristics which would indicate off-grid PVS as a competitive instrument for providing them service. Integrating this technology in the process of universalization calls for several regulatory innovations. The intent of the empirical investigation of the regulatory framework was to identify the shortcomings of the present legislation in this respect and to point to potential remedies. Two principal areas that are in need of further regulation were identified: (i) definition of the amount of public financial resources earmarked for universalization and exact criteria for the use of these funds; (ii) the quality of electricity supply via off-grid PVS.

This chapter gives a brief overview of the development of rural electrification policies during the past decades (9.1), outlines the comprehensive reforms of the electricity sector that got underway in the early 1990s, and addresses their consequences for rural electrification (9.2). The chapter then goes on to identify the main obstacles to a rapid expansion of rural energy supply via off-grid PVS under the recent universalization-of-supply initiative (9.3). Finally, some of the important political factors influencing rural electrification initiatives are also described (9.4).

9.1 A Brief History of Rural Electrification Policies in Brazil

The approaches to rural electrification in Brazil have changed over the past decades. The first programs operating at a national scale originated in the early 1970s. They were managed and financed by the National Institute for Colonization and Agrarian Reform (INCRA) and the national, state-owned electricity holding, Eletrobrás.[103] Later, multilateral development banks provided additional financing and encouraged the integration of rural electrification cooperatives in the process. A third period, starting in the mid-1980s, reduced the scope of rural electrification initiatives, which were now conducted by state-owned concession holders and financed by the Brazilian states. The modest scope of policies in that period was due to the disappointing performance of previous programs, which induced concessionaires to limit their ambitions and pay close attention to commercial interests. National electrification programs were paralleled by isolated private or local

103 Eletrobrás is owned by the federal government and engages mainly in electricity generation and transmission. Besides, Eletrobrás manages the sectoral funds (see 9.3).

public initiatives pursuing the expansion of access to electricity to villages, public institutions, or productive units.[104]

9.2 The Legal and Institutional Aspects of the post-1995 Regulatory Framework[105]

In 1995 the institutional model of the electricity sector was significantly altered by federal reforms aimed at stimulating competition and attracting private investors.[106] Implementing the new model for the electricity sector meant privatizing formerly state-owned utilities, vertically unbundling the industry, and allowing the entry of private agents in order to ensure competitive electricity generation and distribution.[107] The privatization process was prepared for by legislative measures introducing cost-oriented tariffs. Remaining monopolies were regulated with respect to tariffs. To this end, a new regulatory and oversight body, the Agência Nacional de Energia Elétrica (ANEEL), was created (Law 9427/96). In addition, ANEEL holds tenders for generation, transmission, and distribution, grants concessions, and supervises concession agreements.

What follows will briefly describe the Brazilian framework for awarding concessions and explain its consequences for rural electrification:

The Brazilian constitution delegates full responsibility for infrastructure provision to the federal government (Art. 175). The constitution further states that these public services may be carried out by concessionaires or *permissionaires*, who must be selected through competitive auctions, while contractual agreements, supervision, the question of applicable tariffs, and the quality of service are regulated by federal law. The *permissionaire* is a legal figure unique to the Brazilian regulatory setting. While concessions to commercially exploit a well-defined geographical area are awarded through public bidding, a so-called permission may also be granted within a concession region if the contract signed between concessionaire and the federal government does not stipulate exclusivity. Rural electrification cooperatives are typical examples of *permissionaires*. Another legal figure is the *authorization*, the holders of which provide electricity services for private use only.

The main agents on the supply side of the rural electrification process are the distribution concessionaires, who are responsible for transporting energy from the delivery points of the high-voltage transmission system to consumers. Privatization of these distribution companies has achieved the most far-reaching results, compared with generation and transmission companies: 23 electricity concessionaires have been sold for a total of R$ 24.7 billion.[108]

The driving force behind the privatization process was budgetary concerns, a need to maximize proceeds. This explains why binding obligations to extend coverage of electricity services were largely omitted from the agreements between ANEEL and the new private concessionaires. Analysis of the contracts for 52 concession areas with distribution companies shows that targets were agreed upon only in five areas with already very high electrification coverage.[109]

A major obstacle to rural electrification was Decree N° 005 of the National Department for Water and Electric Energy. It mandated that financial participation in investments to provide access to or increase the amount of electricity was to be

104 See Ribeiro (2002), p. 3.

105 This subchapter draws heavily on ESMAP (2002).

106 The past model's structure remained largely unchanged since Getulio Vargas' first regime during the 1930s. For an overview of developments after the 1960s, see Ferreira (1999), pp. 141-175.

107 Laws No. 8.987/95 and 9.074/95 provide a legal basis for tendering concessions for public services, allow large consumers to choose their electricity provider, open access to transmission networks, and provide for the unbundling of integrated companies.

108 See ESMAP (2002), p. 35; 1 R$ is equivalent to 0.35 US$ (October 22, 2003).

109 See Oliveira (2001), p. 44.

compulsory for consumers. The concessionaire was expected to contribute financially up to a certain "limit," which in practice amounted to about 10 percent of investment costs. The remaining 90 percent is not affordable for the majority of rural consumers.[110] Profit-oriented concessionaires demonstrated no eagerness to engage in voluntary service extension for social purposes. In response, the federal government launched its rural electrification programs Luz no Campo in 1999 and PRODEEM in 1994 (see Box 7).

9.3 The Legal Initiative for Providing Universal Access, and Remaining Open Questions

Electricity services will be accessible to all Brazilians in the nearer future if Law N° 10.438 (Universalization Law), approved in April 2002,[111] is handled properly and fully implemented. It expresses a legal commitment to provide access to electricity for the entire population, the so-called universalization of electricity services. ANEEL will play a crucial role in implementing this legislation: among other regulatory functions, it designs and imposes on concessionaires and *permissionaires* targets for full coverage and considers the potential effects on the financial stability of companies in adapting tariffs.[112]

Box 7: Luz no Campo and PRODEEM – Examples of Rural Electrification Policy in Brazil

The efforts of the **Luz no Campo** Program have been focused on grid extension until now. Aiming to connect nearly one million rural households in the four-year period from 1999 to 2002, it is the single largest rural electrification program implemented in Brazil. As of February 2002, 370,000 connections had been established, and another 110,000 were in progress. An additional 647,000 new customers have signed contracts. So far, no off-grid systems have been provided by the program. This can partly be attributed to the relatively modest cost of grid extensions, averaging at R$ 2,326 (US $ 970) per connection. Luz no Campo is basically a credit line that aims at lowering the investment cost barrier for connections by providing favorable financing conditions. According to the legislative framework still in force (Decree N° 005 of the National Department for Water and Electric Energy), the rural consumers (often represented by the municipality) are responsible to bear a substantial share of the connection costs. In spite of the favorable financing conditions, this is still the main obstacle for a faster expansion of electricity supply under the Luz no Campo Program. However, the program has assumed individual characteristics in each state with varying support given to new consumers by the state government. For example, in Bahia the state government assumes the consumers' share of the connection costs.

Experience with off-grid electrification programs in Brazil is only recent and subject to a variety of problems regarding sustainability. The Energy Development Program for States and Municipalities, **PRODEEM**, is the main government sponsored electrification program with a focus on off-grid PVS. It was established by Presidential Decree in December 1994. From 1996 to 2000, PRODEEM provided equipment to 3,050 villages. In 2000, another 1,050 systems were installed. PRODEEM is a centralized program which employs a top-down approach to identify suitable project sites. The equipment is procured by the government at wholesale conditions and allocated free of charge to municipalities upon demand, which are responsible for operation and maintenance. Rather than supplying households, the program has, during a first stage, focused on schools, health facilities and other community installations. A second stage shifts emphasis towards private productive uses of energy. In the future the program will rely upon a variety of service providers for several new pilot projects, including co-operatives, concessionaires, *permissionaires*, multiple purpose rural companies or NGO's. The main objective is to facilitate business development for agents interested in buying and selling off-grid PVS.

Sources: ESMAP (2002); Information gained in expert interviews

The progress made in rural electrification during the 1990-2000 period amounted to about 170,000 new connections per year. If this speed is maintained, universalization will be achieved in 2014. However, assuming increasing marginal costs and a high proportion of potential users with low incomes, universal coverage with electric services will materialize only in the far more distant future.

110 See Valente et al. (2002a).

111 This new initiative was delayed by the energy crisis in 2000.

112 By issuing *Resolução N° 223,* of April 29, 2003, ANEEL has taken an important step. This resolution defines

There are two especially important regulatory areas that will determine the extent to which off-grid PVS will be used in the universalization process: the regulation concerning universal access (targets and financing) and the regulation concerning the application of PVS for public electricity service.

Regulation Concerning Universal Access: Targets and Financing

The *Plano de Metas* (target plan) provides for deadlines for each sub-area of a concession area, progressively increasing around existing distribution networks, within which all consumers must be supplied without extra cost. Consumers will thus be exempt from financial contributions toward the necessary investments (Law 10.438, art. 14). In addition, consumers will be able to lower the times needed for their service connections by paying in advance part or all of the investment costs, while the concessionaires will have to reimburse them when the target deadline arrives (see below).

This target plan was specified in a recent resolution from ANEEL (N° 223, of April 29, 2003). ANEEL defined electrification targets for both the concession area level and the municipality level, each depending on present degree of electrification.[113] The ultimately binding constraint will be the electrification target for the concession area, because municipal deadlines are not allowed to exceed regional deadlines. For concession areas with the lowest indices of electrification, universal coverage is projected for 2016. The concessionaires will have to present a universalization plan (*Plano de Universalização*) setting out the steps necessary to fulfill the objectives set. Implementation will be monitored and enforced by ANEEL.

Thus far around 2.5 million rural households have not been served by concessionaires because service is not attractive in commercial terms.[114] The financing of the investments required to provide universal access to electricity will thus be the crucial issue. ABRADEE (Brazilian Association of Electric Energy Distribution Enterprises) estimates that total investment costs will be in the range of R$ 8.5 billion, based on average connection costs over the past 10 years. Even this optimistic scenario – marginal costs tend to rise considerably due to increasingly difficult geographic conditions – requires an annual investment of approximately R$ 500 million.

Several financing mechanisms for rural electrification have been made available or extended under the new initiative. Sectoral funds are available as soft loans (Global Reversion Reserve; *Reserva Global de Reversão* – RGR) or grants (Energy Development Account; *Conta de Desenvolvimento Energético* – CDE), and cross-subsidies are provided for users eligible for social tariffs. Both funds and cross-subsidies are available only for agents who are embedded in the legal framework of the electricity sector (i.e. concessionaires or *permissionaires*). A number of PV activities have been carried out by agents operating outside this institutional setting.[115] This potential conflict will be addressed below.

The RGR was created by Law 5.655/71. Concessionaires are allowed to pass on their compulsory contributions to this sectoral fund by adding them to their tariffs. The burden is thus borne by electricity consumers. Originally earmarked for the eventual repurchase of public concessions by the

specific targets and time horizons for reaching universalization. See below.

113 In a specific area with a relatively high rate of electrification (say 90 %), universal access has to be reached rapidly (say within 3 years). In another specific area with a relatively low degree of electrification (say 50 %) universal access may be reached more slowly (say within 12 years).

114 This figure is based on a estimation of ABRADEE. See Pereira (2002). According to this estimation Brazilian national rural electrification rate amounts to approx. 65 % - own calculation based on Pereira (2002). According to other sources, national rural electrification rate amounts to approx. 75 %. See Ribeiro (2002), p. 13.

115 See Ch. 11.1 to 11.3 for such examples.

state, Law 8.631/93 released the fund's resources for lending to rural electrification programs. The soft loans granted by this fund are accessible through Eletrobrás. Law 9.427/96 decreed that 50 % of the resources of RGR should be directed to the North, Northeast, and Mid-West regions and that the remaining 50 % of these funds should be allocated to programs for rural electrification (Luz no Campo, see Box 7), to the electrification of low-income consumers, and to energy efficiency programs.[116] Recently the fund's existence was extended until 2010.

The CDE, another sectoral fund created by Law 10.438 (Article 13) and planned for 25 years, is also administered by Eletrobrás. It aims – somewhat vaguely – at encouraging the utilization of the energy potential of the states but also at promoting universalization of access to electric energy. Its resources stem from (a) annual payments of the concessionaires for the use of public facilities, (b) fines levied by ANEEL, and (c) annual quotas paid by the distribution companies. Only the first two sources are earmarked primarily for universalization purposes.[117] The quotas (c) represent by far the largest source. They stem mainly from a tax paid by all consumers and collected by the concessionaires via the electricity bill. The resources from the CDE are given as grants. At present it is not clear what share of the CDE will be used for universalization. The extent to which resources from the CDE will be available to finance the universalization process will be the main factor determining whether the huge investments will prove financeable and the targets set will be met.

Aside from sectoral funds, there are also cross-subsidies available to distribute the costs of expanding rural energy supply among the consumers of one concession area. This issue is closely related to tariff regulation. Consumers served by the electric grid are charged differentiated tariffs and are classified in accordance with certain socioeconomic characteristics.[118] If consumption falls below a certain threshold, the social lump-sum tariffs apply, which – like all tariffs – differ between concession areas and vary between 2 R$ and 7 R$ per month.[119] Law N° 10.438 has enlarged the low-income category (*residencial baixa renda*). In the past, households consuming up to 30 kWh per month were eligible for the low-income tariff. Now, households consuming up to 80 kWh, or even 220 kWh under conditions as yet to be regulated by ANEEL, will pay the subsidized tariff. Consequently, the number of low-income consumers will increase significantly. Because this tariff does not cover the costs incurred, it is heavily cross-subsidized.[120] For some concessionaires, the ratio of social-tariff clients to clients paying the common (i.e. cost-oriented) tariff is already substantial.

Disproportionately many future users of an expanded electricity supply will qualify for the social tariff, and this may place some concessionaires in a precarious revenue situation.[121] An even larger share of consumers paying less than the actual cost of service would, in this case, have to be subsidized by the remaining customers. This would mean a disproportionate bias against concession areas with low electrification rates and

116 In 1999, the RGR generated close to R$ 1 billion and it is expected to yield around R$ 1.2 billion in 2010. This implies that at least 250 million will be invested in the electrification of rural and low-income areas in the respective regions, aside from energy efficiency programs.

117 Up to 2008, the use of public facilities is expected to yield only around R$ 16 million, but this is expected to rise to R$ 248 million by 2012.

118 The main categories are: residential, commercial, industrial, public service, rural, public illumination, own consumption, and public administration. See http://www.aneel.gov.br/arquivos/pdf/tarifas_conceituacao.pdf.

119 See Santos (2002), pp. 169-172 and ANEEL Resolution 246. The relevant subsidized tariff classes in the context of rural electrifications are: i) *residencial baixa renda*, ii) *rural agropecuária residencial monofásica ou bifásica a dois condutores*, iii) *rural agropecuária residencial bifásica a três condutores*.

120 Santos (2002), p. 174 gives an overview of the level of subsidization.

121 ABRADEE estimates that of the 2.5 million rural households to be connected 56 % will qualify for the low-income tariff *baixa renda*. See Pereira (2002).

high shares of low-income households, unless transfers are forthcoming from better-off concessionaires or outside the sector. Under the new law – under which concessionaires are required to bear the full investment costs – pressure for substantial tariff increases is expected. Detailed studies on the impact of this requirement on tariffs should be ANEEL's first initiative.

Regulation Concerning the Application of Off-grid PVS for Public Electricity Service

Defining target deadlines is one thing, regulating the instruments used in the process another. While grid extension has been the dominant means of electrification in the past, off-grid PVS have a competitive advantage for remote and sparsely populated areas. A certain proportion of the areas to be electrified displays these characteristics, although the size of this proportion is a controversial matter and needs further research.[122] If the market potential is to be realized in areas where off-grid PVS represent the least-cost alternative, several obstacles have to be removed by means of appropriate regulatory action. What this means is integrating PVS technology in the legal framework of public-service provision (current and past off-grid PVS projects have largely operated outside the regulated electricity market).

The tariff applicable for off-grid PVS has not been regulated yet. The relevant alternatives would be either to apply the prevailing grid-electricity tariffs or to use differentiated PVS tariffs. Many experts note that grid tariffs probably also apply for energy provision via PVS, since the relevant legal documents from ANEEL do not specify the source of the electricity concerned. Another argument cited for equal treatment of PVS and grid supply is that it is politically not justifiable to charge more for PVS supply, considering that PVS are of lower capacity than the grid. Still, the tariff to be charged for electricity supply via PVS is a matter of uncertainty among the concessionaires. If the grid tariffs are applied, almost all PVS customers will qualify for the low-income social tariff, since PVS up to a size of 250 Wp typically deliver less than 30 kWh per month.[123]

It is necessary to define the minimum quality of service delivered by an off-grid PVS that fulfils the obligations deriving from a public concession. ANEEL needs to establish indicators to monitor service quality and quantity; these would include e.g. the frequency and duration of supply interruptions, etc. While there are such definitions for grid electrification, they will have to be adapted to suit PVS technology.[124]

Closely connected with this issue is the division of responsibilities regarding maintenance. Corresponding to the traditional grid, an entry point has to be defined for the different features of an off-grid PVS in order to clarify the division of responsibilities for maintenance between service supplier and customer.[125]

Law 10.438, Art. 14, allows for anticipating electrification, the so-called *pré-eletrificação,* if the consumer is prepared to advance the investment cost. The concessionaire will have to reimburse the customer when the target deadline defined by ANEEL arrives. It is recognized that a considerable market potential for off-grid PVS might derive from its use on a transitional basis. It is not clear yet whether the amount and quality of elec-

122 The estimated market potential varies widely between different sources. Pereira et al. (2002), p. 144, expect 100.000 potential users of PVS in Bahia alone, whereas ABRADEE and Eletrobrás calculate 25.000 to 50.000 users for Brazil as a whole (information gained during expert interviews). These differences highlight insecurity about the potential market for off-grid PVS and the technology's usefulness. See also Ribeiro (2002), Ch. 6.1 for an estimate of the market share to be reached via PVS.

123 Information gained during interviews with representatives with CEMIG (March 31 to April 1, 2003).

124 For proposals regarding this issue see Valente/ Correia/ Pereira (2002) and Santos (2002). ANEEL has recently hired a consultant to devise a proposal for quality of service regulation for off-grid PVS. The presentation of results is expected in August 2003.

125 For a further discussion, see Santos (2002), Ch. 5.3. See also Ch. 11.4 of the present study for a description of the entry point concept.

tricity provided by off-grid PVS will be sufficient to be considered "definite electrification" (see above). On the other hand, implementation of *pré-eletrificação* gives rise to the question of how the low-income rural population will deal with the administrative tasks involved and how the target group will cope with the need to advance the investment costs. Technical and financial assistance will have to be designed accordingly.

As regards the implementing agents, according to Law 10.438, Art. 15, off-grid PVS are a technological option only for *permissionaires*, not for concessionaires. While this appears to be under revision, the future role of *permissionaires* is not clear: the political power of the concessionaire makes it unlikely that commercially interesting areas will be auctioned off to competitors. This means that *permissionaires* will be left to serve only commercially unattractive areas. Unless an independent entrepreneur displays considerable comparative advantage: What incentives might induce him to exploit a commercially unattractive area?

Another open question is the future role of existing (and forthcoming) off-grid PVS projects implemented by other agents (NGOs, rural associations, etc.) and how they might be integrated in the supply expansion that the concessionaires are required to provide. One conceivable scenario is that these agents might act as delegated service providers of the concession holder. This would have the one advantage that the experience gained by these agents in managing PVS projects could be preserved and enlarged. However, there are doubts concerning quality of service and the technical and financial sustainability of PVS projects run by such agents (see Chapter 11).

To sum up, the new law obliges the concessionaires to provide universal access to electricity services and stipulates provision of additional financial resources to finance universalization, and thus it represents an opportunity for the rational dissemination of off-grid PVS. However, some main obstacles facing a rapid expansion of rural electricity supply are i) the huge investments necessary, ii) uncertainty about the levels of subsidies from the sectoral funds (especially CDE) that will be available for this purpose, and iii) the expected negative impact on the financial situation of the concessionaires, especially those serving areas with low electrification rates and high shares of low-income households. While these obstacles relate to the universalization process as a whole, there are some additional uncertainties specifically bound up with the PVS technology. The most important uncertainties relate to the tariff applicable and the quality of service to be guaranteed. Unless these obstacles are removed, rural electrification via off-grid PVS may not realize its full potential.

9.4 Political Factors Influencing Rural Electrification in Brazil

In practice, implementation of PVS projects has to consider a wide range of political factors, since these significantly influence their outcome. First, clientelist legitimation strategies[126] are an important motive behind resource allocation. Second, fragmentation between administrative levels and party-political interests creates blockades and incoherencies in the formulation of electrification projects. Third, the regulatory process is subject to political negotiation.

Clientelism is a common, albeit informal, source of legitimacy in political processes in Brazil. Its influence is difficult to assess. Nevertheless, clientelism was mentioned in almost every one of our expert interviews as well as in numerous user interviews. During the interviews in Valente (Bahia), various users mentioned that they were barred from grid extension for being members of a rural association (APAEB)[127] which sympathizes

126 Clientelism refers to the selective preference for political allies or groups that are considered important for political influence. Allotment of aid programs thus is not necessarily related to existing needs. *Assistencialismo* refers to the fact that certain social policies create a mentality of dependence on external help. This is assumed to eliminate incentives for people to engage in economic activities.

127 See Ch. 11.1

with the political opposition, or they stated that they had been offered connection to the grid if they voted for the governing mayor. The selection of municipalities and associations in the CAR project[128] (Bahia) has (at least in the past) been suspected of being tied up with political interests. In addition, parliamentarians are able to channel special resources from the federal budget to certain tasks in their home regions through so called *emendas parlamentares*.[129] The *emendas parlamentares* are commonly rather small amounts of money which are used for small community projects and follow a clientelist rationale.[130]

Fragmentation between agents at different administrative levels can slow down decisions or negatively affect the outcome of PVS projects. At the national level at least four ministries are involved in rural electrification.[131] They are carrying out different projects, some of them with rival competences. In addition, state governments and ministries have to be considered as well, since they are also involved in the electrification process, usually under the scope of their specific tasks.[132] Finally, local authorities play an important role too, since they are involved in the implementation of almost all programs. All the authorities mentioned are subject to competing political and party-political interests. This means that scarce resources, especially in the case of *emendas parlamentares*, are frequently not coordinated and are hence ineffective. In addition, these resources appear not to be especially reliable: In the municipality of Diamantina, a promised *emenda parlamentar* has not been paid out because the responsible federal bank (Caixa Econômica Federal) refused payment.[133]

The **process of regulation** proceeds in a context marked by different and in part conflicting interests. During various interviews these different positions became visible and proved to be of importance. As regards PVS, it is less the existence of veto players trying to impede implementation than a lack of interest on the part of the important players that obstruct any more clear-cut regulation.[134] Among the agents involved, the ones interested in the dissemination of PVS are generally of less importance and are therefore hard pressed to influence the process. In particular smaller influence groups, like the Brazilian Association of Renewable Energy Enterprises (ABEER), seek to circumvent these obstacles, though without meeting with much success up to now.[135]

10 Socioeconomic Conditions in the Regions of the Field Study

The field study focused on PVS projects located in the states of Alagoas, Bahia, and Minas Gerais (see Map 1). In a broader sense, the project regions visited belong to the semi-arid region of the Brazilian Northeast. Minas Gerais is usually not considered part of the Northeast. However, the sub-

128 See Ch. 11.3.

129 *Emendas parlamentares* are usually negotiated in return for approvals in parliamentary voting.

130 A representative of MAPA stated that the allotment as well as the tendering of the financed projects primarily serve clientelist interests. Interview at MAPA on March 27, 2003.

131 The Ministry for Mines and Energy (MME), the Ministry for Agriculture and Food (MAPA), the Ministry for Agrarian Development (MDA), and the Ministry for National Integration (MINA).

132 In Minas Gerais, the governor announced a universalization plan prior to the national universalization law. Information gained during interviews at the Secretaria de Estado de Desenvolvimento Econômico of Minas Gerais on March 31, 2003.

133 In consequence, the municipality had to finance the electrification measures with own resources. Cancellation of the electrification order was not possible since contractual obligations had already become effective. Information gained during interviews with the mayor of Diamantina and CEMIG officials on April 2, 2003.

134 CEMIG officials stated that clearer arrangements would certainly encourage and facilitate the use of PVS. See Ch. 9.3.

135 Information gained during interviews with representatives of MME, MAPA, ANEEL, Eletrobrás, ABRADEE and ABEER in April 2003.

Map 1: Political and Administrative Breakdown of Brazil – Location of Project Regions

Source: IBGE

region of Vale de Jequitinhonha, which we visited, displays social and geographical indicators that resemble those of the semi-arid Northeast. Aside from this, the Vale de Jequitinhonha is part of the area targeted by the regional development agency for Northeast Brazil (ADENE). In the following section, the Northeast will be characterized briefly in socioeconomic and demographic terms. The Northeast is the poorest macro-region of Brazil, with the lowest HDI (0.608 in 1996) of all of Brazil's macro-regions.[136] About 32 % of Brazil's poor live in this region, and 63 % of the rural poor are concentrated in the Northeast. This means that a share of 39 % of the population is poor.[137]

Rural settlements in the Northeast are frequently highly dispersed, especially in the *Sertão*, the arid and semi-arid region in the heartland of the Brazilian Northeast. The southern part of the *Sertão* extends as far as the North of Minas Gerais. For reasons bound up with climatic and demographic conditions, agricultural and industrial activities are faced with significant obstacles here. In particular, irrigation is an issue of great importance for the development of agricultural activities.

The highly dispersed rural settlements commonly exhibit the lowest per capita income and educational levels. Average school attendance in the Northeast (3.9 years) is well below the national average of 5.3 years, and the illiteracy rate (28.7 %) is almost double the national rate of 14.7 %.[138] The population typically engages in small farming either as day laborers or as owners of small farms of up to 50 ha.

The rural population of the Northeast is especially short of basic infrastructure services. This goes for educational and health facilities as well as for water, transportation, and electricity. ABRADEE estimates that of the total number of rural households without electricity in Brazil (2,552,707), a share of 62.6 % (1.597.599 households) are located in the Northeast.[139] In addition, electricity demand is as a rule quite low in this region. An indicator for this is the high share of consumers who pay the low-income maximum tariff *baixa renda*[140] (see also Table 4).

Assessing the income of the rural population during the interviews in the field proved to be a methodological problem, because in rural areas many transactions are conducted on a non-monetary basis. Frequently goods are exchanged when they are needed. Monetary income is highly irregular and low. One exception is pensions and social benefits (*bolsa escola, vale gas*) that are paid out in money and provide for a small but stable monetary income base. When a higher amount of money is needed, an animal (typically a goat or sheep) is sold at the local market. Another source of income is donations from family members working in cities.

The following sections briefly outline the conditions in the districts visited.

Table 4: Electrification Rates and Poverty Indicators

State	General Electrification Rate (2000)	Rural Electrification Rate (1999)	Share of Poor (2001)	Share of Consumers of the Respective Concessionare Classified as *Baixa Renda* (Dec.02)
Alagoas	88.6 %	75.9 %	62.7 %	47.5 %
Bahia	80.8 %	48.9 %	56.7 %	62.9 %
Minas Gerais	95.9 %	80.3 %	25.3 %	46.5 %

Sources: Pereira (2002); Ribeiro (2002), annex I

136 The other macro-regions are: North, Midwest, Southeast, and South.

137 See Winrock International - Brazil (2000), pp. 25-28.

138 See Winrock International - Brazil (2000), p. 18.

139 For the three states in question, the number of rural households without electricity are: Baiha: 505.000, Minas Gerais: 129.000, Alagoas: 58.000. See Pereira (2002).

140 See Ch. 9.3.

10.1 Alagoas – The Districts of São José da Tapera and Pão de Açúcar

Alagoas is a state marked by diverse geographic, climatic and hence socioeconomic conditions. The coastal area and part of the hinterland is well suited for agricultural activities (the main agricultural product is sugar cane). The semi-arid regions are still good for producing, for example, tobacco and fruits. The sparsely populated arid region in the western part of the state, finally, offers only reduced agricultural opportunities.

The state of Alagoas (together with the state of Maranhão) shows the lowest record in terms of HDI among all Brazilian states. The district of São José da Tapera was ranked Brazil's tenth most miserable district in 1998.[141]

The interviews conducted during the field study revealed a substantial amount of illiteracy throughout the projects visited. This is confirmed by official statistical data: São José da Tapera has an alphabetization rate of 54.4 %, Pão de Açúcar 61.4 %; both figures are well below the state average.[142]

Although the two districts are located quite close together, the area of the SHS project in São José da Tapera seemed to offer more favorable conditions than the one in Pão de Açúcar. This could be due to higher rainfall in that area, which fosters agricultural activities and better infrastructure conditions that facilitate marketing of agricultural production. This was shown by, among other indicators, more frequent possession of relatively expensive appliances like TVs. Whereas in São José da Tapera the great majority owned such appliances, in Pão de Açúcar only a few persons owned electric appliances apart from lamps or small radios.

The housing units of SHS users generally consisted of stone or bricks and had concrete floors. Generally, the housing units equipped with an SHS were of higher quality than those without SHS. This observation may indicate that the poorest part of the population has not been reached by the local PVS project (see also Chapter 11.2).

10.2 Bahia – The Districts of Arací, Canudos, Serrinha and Valente

Bahia is the largest state in the Northeast and has the country's highest number of people without access to electricity. The projects visited are located in the arid and semi-arid *Sertão*. The main occupation of the rural population is subsistence agriculture. The incomes of the four districts visited are considerably below the state average.[143]

The demographic characteristics of the districts are shown in Table 5. The rural educational level is low and there are few employment opportunities available apart from agriculture.

Table 5: Demographic Characteristics of the Districts Visited

Municipality	Illiteracy Rate	Population	Urban		Rural		Populational Density (inhab./km^2)
			Male	Female	Male	Female	
Arací	42.2 %	47,584	7,887	8,302	16,214	15,181	30.19
Canudos	29.3 %	13,761	3,411	3,601	3,546	3,203	4.59
Serrinha	23.8 %	71,039	…	…	…	…,	118.06
Valente	22.8 %	19,145	4,543	4,968	4,955	4,679	51.40

Sources: SEI (2002), IBGE (2000)

141 See The Economist, August 16, 2003, p. 39. Brazil has 5,561 districts from which 1,792 are located in the Northeast. See "Brasil em Síntese", www.ibge.gov.br, 10/10/03.

142 See IBGE (2000).

143 See SEI (2002).

One exception to these occupational characteristics is Valente, which has a strong agricultural cooperative (APAEB). This cooperative not only enhances the social organization of farmers and engages in capacity-building, it also opens up new marketing possibilities for agricultural products. Moreover, APAEB also offers micro-credits and creates employment through its own institutions.

The households visited in Valente were well equipped with domestic electric appliances. This is probably due to the availability in the APAEB supermarket of appliances suited for SHS (see also Chapter 11.1).

10.3 Minas Gerais – The District of Diamantina

Although Minas Gerais is a wealthy state in the Brazilian context, especially the northern part, the Vale de Jequitinhonha, is one of Brazil's poorest regions. Diamantina is located in a formerly rich mining area. One of the main occupations there is thus still extraction of diamonds (and gold), which is conducted as a family business. However, nowadays valuable stones are very rare. Apart from digging for diamonds, most people engage in small farming, working on a subsistence basis or as day laborers. 54 % of the area's population earns up to one minimum salary.[144]

At 87.2 % Diamantina's literacy rate is the highest of all districts examined.[145] The area is less arid than the ones visited in Alagoas and, especially, in Bahia. Water supply is not the main bottleneck for local development. There are hardly any work opportunities in rural areas. A joint project of CEMIG/GTZ is seeking to remedy this by promoting agro-industrial production structures and creating new employment opportunities.[146]

Generally, the households visited were very poor in terms of their possession of goods.[147] Apart from schools, nobody owned a TV, and only few households had a radio. A CEMIG study showed that about 87 % of the population owned not one good of any monetary worth. The population's housing is generally built of adobe, and the vast majority has no sanitary installations.[148]

11 Description and Assessment of the Projects Visited

The following section presents the empirical results concerning the main problem dimension of "project management," with an exclusive focus on residential SHS.[149] This chapter builds on the concepts developed in Chapter 7.

In assessing the delivery models investigated, the criteria of technical and financial sustainability play an important role. There are no generally accepted definitions of technical and financial sustainability in relation to SHS projects. For the purpose of the present investigation, the following concepts will be used:

Technical sustainability is defined here in a rather narrow manner, focusing mainly on the aspect of operational performance from the point of view of the user in need of reliable energy service.[150] A SHS project is termed technically sustainable if the systems continuously provide the energy necessary to meet the load they are designed for, with a minimum of technical failures.[151] Technical sustainability thus has very

144 See Diniz/ Campos/ Diniz (2001), p. 10.

145 See IBGE (2000).

146 See Coelho (2002) and Box 8.

147 Canudos showed similar characteristics in terms of possession of goods.

148 See Diniz/ Campos/ Diniz (2001), pp. 11-16.

149 Community PVS (schools and community centers) will be considered in Chapter 12 (development impacts).

150 For the technical details of off-grid PVS, see Box 1 and Annex A1.

151 There is only very limited empirical evidence on the technical performance of stand-alone PVS, and further

much to do with the quality of electricity service over time as well as with efforts required to guarantee this quality. Technical sustainability depends mainly on the following factors: the dimensioning and design of the system, the quality of installation and system components, system operation, quality and availability of spare parts, and maintenance services.[152]

The minimum requirement for a SHS project to be **financially sustainable** is that the costs of the resources necessary to keep the systems operating technically once they are installed are available without any (continuous or sporadic) need for external resources. More precisely, this means that at least the costs for O&M should be covered internally, i.e. by users.[153] Still, requirements for financial sustainability depend on the particular design of the delivery model chosen. Under a sales model, e.g., financial sustainability will require a cash flow higher than just the amount necessary to cover O&M costs, since capital expenditures also have to be met. Financial sustainability is mainly influenced by user ability to pay and willingness to pay (the latter of which depends on technical sustainability), the enforceability of payments, and the amount of investment and O&M costs to be covered.

Clearly, technical and financial sustainability are interdependent: financial sustainability is compromised by poor technical performance and, at the same time, it has to be ensured that the financing for human and physical inputs necessary for sustainable technical performance is available over the time horizon of the project.

The following sections, 11.1 to 11.4, present detailed descriptions and assessments of the four projects visited. *Readers not primarily interested in the details of delivery models may skip directly to Section 11.5,* which summarizes the findings of the previous sections and draws some conclusions on key factors and instruments needed to attain technical and financial sustainability in SHS projects.

11.1 The APAEB Energia Solar Program in Bahia[154]

APAEB (Associação dos Pequenos Agricultores de Valente)[155] is an NGO located in Valente (Bahia), which was founded in 1980 as an association of small farmers.[156] The main objectives of APAEB are, among other things, to improve human living conditions in rural areas, to represent the interests of members, to stimulate education and cultural activities, to enhance industrial production and marketing of agricultural products. APAEB hence aims at an integrated rural development approach which includes numerous activities. The overall association is based on a strong spirit of solidarity.

One of these activities is a rural electrification program which started in 1995. Up to now APAEB has sold and installed more than 1,000 SHS, 600 of which have been financed by credits

research is needed to define appropriate indicators. See Mayer/ Heidenreich (2003). Nieuwenhout et al. (2001), p. 466, give an overview of the operational status of SHS in developing countries. The share of non-operational systems varies between 2 % and 90 %!

152 See Vervaart/ Nieuwenhout (2000) for a comprehensive discussion of the factors that have an effect on the technical performance of SHS. See GTZ (2000) for an overview of the technical standards of SHS installations.

153 The aim of these projects is to electrify dispersed rural households which are relatively poor. Therefore, full cost coverage is often not feasible, either with grid extensions or with PVS. In particular, the high investment costs may require subsidies. Still, for a project to be self-sufficient, it should finance the O&M costs by internal means and not depend on the inflow of external resources. See Ch. 7 and Wade/ Lambert/ Ferguson (2002), p. 21.

154 This section is based on information gained during interviews with users as well as with APAEB and COOPERE representatives in the district of Valente on February 25, 2003; APAEB (2001, 2002); Valente et al. (2002b) and Ghirardi (1999).

155 Association of Small Farmers of Valente.

156 In 1980 Brazil was governed by a military government that prohibited the founding of cooperatives. APAEB therefore chose the form of an association. See APAEB (2002), p. 113.

from a revolving fund. APAEB has also equipped a few schools with larger community PVS, which have usually been financed by international donors or in cooperation with PRODEEM.[157] Aside from this, PVS are available to operate electric fences for keeping goats and sheep.

In the following section the focus will be on the credit-sales modality as well as on residential systems.

11.1.1 Description of the Delivery Model

The delivery model can be labeled as a (cash and) **credit-sales model with a revolving fund**.[158]

Financing

As is typical for sales models, the overall **investment costs** are covered by users. APAEB`s micro-credit institution COOPERE (Cooperativa Valentense de Crédito Rural) established a revolving fund especially for PVS financing, to enable poor members to buy PVS. The fund was donated by international donors in 1995. To obtain a micro-credit, the user must be a member of both APAEB and COOPERE.

The fund provides an interest-free credit[159] which covers the overall acquisition costs of the PVS. The credit period is 8 years, with annual repayment rates. To facilitate user repayment (users mainly rely on agricultural income), APAEB introduced a conversion currency: goat meat. For a 64Wp SHS the equivalent repayment rate expressed on a monthly basis is 6 kg of goat meat (about 18 R$).[160] The credit terms were based on estimated monthly expenditures for alternative energy sources (candles, kerosene, etc.) of 14 R$ per month.[161]

The user is generally responsible for covering his **O&M costs**, as he is the owner of the SHS. This means that the user has to pay for spare parts and if necessary for technical service as well.[162]

A special guarantee fund (ATER) was created to support the technical sustainability of the delivery model. Users who are given a micro-credit are required to pay 10 % of the value of their credit into the guarantee fund, which pays for technical service during the first three years of the contract. During that time the user is only required to pay for spare parts that are no longer covered by guarantee. After the three years the user has to cover all maintenance costs out of pocket (technician and spare parts).[163]

Division of Responsibilities

The SHS are **marketed** within the actuation area of APAEB. APAEB buys the equipment and spare parts and sells them to association members in its own supermarket. Potential users are informed about SHS and its costs and capacity during regular APAEB member meetings.[164] The user decides when to buy the SHS and what size she wants to purchase. The transaction hence depends to a

157 PRODEEM donated a 2 kWp PVS to APAEB which was installed by the NGO Winrock, see Winrock (2000), pp. 4-5.

158 See also Tables 6 and 7 for summarized description and assessment.

159 The fact that the users do not have to pay interest on the capital borrowed means that they do not incur capital costs.

160 These figures relate to the year 2000. The price for the overall system (64 Wp panel, 150 Ah battery, 6 A charge controller, materials) including installation is ca. US $ 865. The additional charge for the maintenance fund (ATER) amounts to US $ 86.50. See Valente et al. (2002b), p. 97 ff.

161 See Ghirardi (1999), p. 4.

162 The technician was initially an employee of APAEB. Actually he is an independent entrepreneur and is hired when needed.

163 Apart from the technician's salary of 2 R$/h, the user has to pay 0.36 R$ per km and must provide lunch for the technician. See Valente et al. (2002b), p. 92.

164 In exceptional cases non-members may borrowed a micro-credit if they are member in another cooperative.

large extent on the preferences and financial resources of the user. However, under the credit-sales modality, access to a SHS also depends on the availability of resources in the revolving fund.[165] The APAEB delivery model assigns the main responsibilities to the user, since the user is the owner of the SHS and all of its components.

Installation is carried out by a technician, who also provides maintenance service. The charge for the installation service is 50 R$.[166] The typical features of an APAEB SHS include a 64 Wp panel, a 150Ah automotive battery, a 6A charge controller, as well as lamps, electronic ballast, and cables. This size is designed to operate 3 lamps, a radio, and a small black/white TV. However, if the user needs more capacity, he can enlarge the system. Additional smaller PVS for electric fences are available in the APAEB supermarket in Valente.[167]

The user is responsible for the **O&M** of the SHS. In case of malfunctions the user has to decide whether to call the technician and pay for his service or whether to fix the problem by some other means. The guarantee fund, ATER, pays for the technician's service only during the first three years.

User capacity-building and information is provided during the regular APAEB meetings. The users are informed about the use and operation of the SHS, about the capacity of the system in particular, and about battery maintenance. The technician provides additional information to users during installation and maintenance. Figure 9 illustrates the delivery model.

11.1.2 Assessment of the Delivery Model

Financial Sustainability

Under this credit-sales model, financial sustainability requires coverage of O&M costs as well as coverage of the installments necessary for the revolving fund to recover the capital.

The conditions for repayment of the interest-free micro-credits, which are flexible and adapted to the situation of users, have a positive effect on user ability to pay and thus on financial sustainability. Seasonal income fluctuations can be balanced out by charging annual (instead of monthly) installments, and the purchasing power of debtors is safeguarded by indexing repayments to an important source of income (goat meat).

On the other hand, indexing repayments to the price of goat meat poses a threat to the sustainability of the revolving fund. Whereas inflows to the revolving fund depend on the local price of goat meat, outflows depend to an important degree on the exchange rate: about 50 % of purchase costs depend on imported equipment (panel, charge controller). Therefore, the capital stock of the revolving fund is at a high risk of constant depletion whenever the Brazilian real is devalued. This actually seems to be taking place.[168] The shrinking fund places limits on the number of PVS available on a credit basis, and this could lead to an end of credit sales in the future.

The collection performance of installment payments seems to be good, with rather low rates of nonpayment.[169] Factors that favor good collection performance are clear-cut contractual arrangements, the spirit of solidarity and commitment

165 As these resources are limited, usually only 64 Wp (simple) systems are available under the credit sales modality, in order to give access to as many buyers as possible.

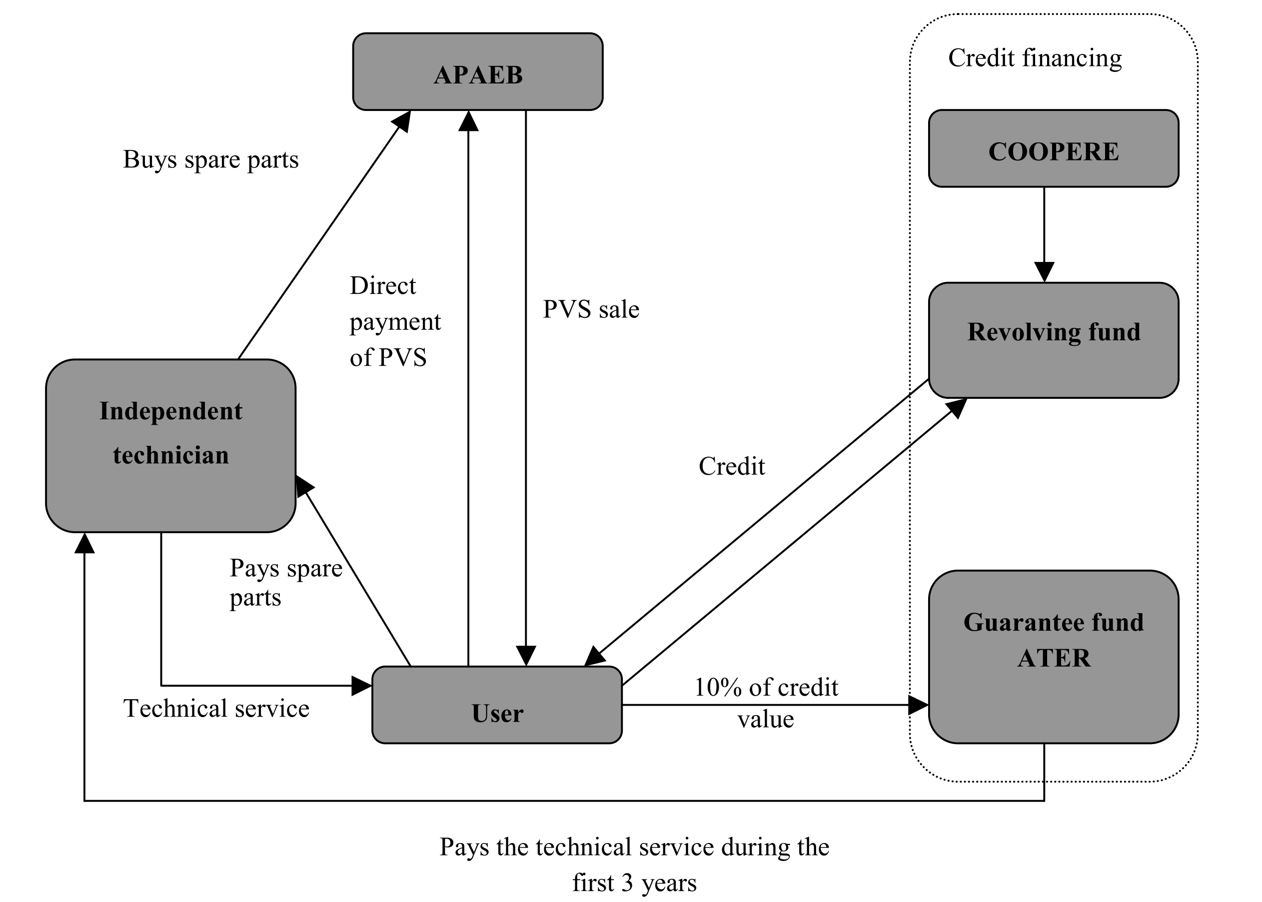
166 See Valente et al. (2002b), p. 86.

167 The PVS for electric fences are among the rare productive applications observed during the field study. A typical APAEB PVS for electric fences serves about 40 km fence line.

168 See Valente et al. (2002b), p. 97 ff. However, APAEB representatives stated that price fluctuations for goat meat show a high correlation with exchange rate (R$ / US $) variations.

169 Information gained during interviews with users as well as with APAEB and COOPERE representatives on February 25, 2003. However, Ghirardi (1999), p. 12, reports an increase in the rate of non-payment from 0 % (1996) to 14.7 % (1998).

Figure 9: Delivery Model APAEB



Source: Own illustration

between the members, and the authority and strength of the local institutions APAEB and COOPERE.

In the past, problems have been reported concerning the collection of the service fee that has to be paid after the three-year guarantee period.[170] Apparently, collection has not been enforced, and this constitutes a threat to financial sustainability. The APAEB/COOPERE management reacted by outsourcing the maintenance service: the status of the technician was converted from that of an employee of APAEB to that of an independent professional who provides the service at his own risk and is thus highly interested in collecting maintenance charges. However, there seems to be a lack of transparency concerning the costs for technical service. Users were not aware of what share of the maintenance costs went for the technician's wages and what share is represented by the price of spare parts.

Technical Sustainability

In the cases examined, installations were of rather low quality. One general problem was presented by loosely fixed cables. In some cases charge controllers had been disconnected or tampered with by users. The (low) quality of installation is

170 See Valente et al. (2002b), p. 86.

partly responsible for the technical failures that typically occur in APAEB's SHS.[171]

In the field of O&M, APAEB created a local market for spare parts and electric devices (DC) for SHS in its supermarket, which is important to ensuring the technical sustainability of the systems. Another advantage is that a local technician is responsible for maintenance and is quite easy to contact.

There appears to be room for improvement concerning the quality of service provided by the local technician, whose qualifications seem to be limited. In addition, the quality of spare parts is usually low, as users prefer to buy the cheapest components.[172] This seems in part to be related to the fact that users seek to avoid the financial burden of O&M costs after the three-year period (it has to kept in mind that monetary incomes are relatively low and irregular). Necessary maintenance is postponed or low-quality self-made solutions are preferred.

One disadvantage of APAEB's PVS project has to do with a lack of quality management. This is noticeable in the lack of quality control activities, the low quality of spare parts, and failure rates.[173]

In the cases examined evidence was found of insufficient user information. Users were not well informed about the capacity of their SHS and about maintenance tasks. This lack of information leads to misuse and inappropriate maintenance and hence reduces technical sustainability and raises long-term maintenance costs.[174]

171 See Valente et al. (2002b), pp. 88-91

172 APAEB therefore uses automotive batteries instead of special solar batteries. This reduces the initial costs of the SHS, but raises maintenance costs. Also, the ballast used for the lamps caused problems in almost all households visited. Electronic ballast and batteries account together for almost 60 % of the failures that have occurred; see Valente et al. (2002b), p. 89.

173 See Valente et al. (2002b), pp. 86-91.

174 Valente et al. (2002b), p. 104, state that about 7 % of failures are due to the user's lack of knowledge of how to use the PVS.

Other Factors

The most important advantage of APAEB is its holistic vision of rural development. The association offers a wide range of activities, electrification being only one which complements the others. This approach makes it possible to improve income generation and quality of life at the same time. These are conditions important to ensuring the project's financial sustainability.

Moreover, under the APAEB model it is the user who decides on when to buy the SHS and what capacity he needs. This fact and the deed to the SHS increase the ownership and participation of the rural population. On the other hand, these typical features of a sales model exclude the poorest population, since the model is predicated on a relatively high ability to pay. Poorer households in particular have problems in repaying the credit as well as in covering the maintenance costs.

One disadvantage is the fact that APAEB's project is not coordinated with COELBA's (concession holder for electricity distribution in Bahia) grid extension plans. It was observed that the distance to the grid was in many cases less than 200m. Proximity to the power grid reduces willingness to pay, since tariffs for grid electricity are lower and the grid provides higher capacity. As a consequence of the Brazilian government's initiative to universalize electricity supply, COELBA's efforts to expand coverage in the actuation area of APAEB may increase in the future. Therefore, APAEB and COELBA should coordinate their electrification activities in order to avoid user misinvestments.[175]

175 Lack of coordination with grid extension is common for all delivery models visited, except the CEMIG model (see below).

11.2 The Program Luz do Sol of FTV in Alagoas[176]

The Fundação Teotônia Vilela (FTV), an NGO, initiated the program Luz do Sol in the semi-arid region of Alagoas in 1996. It was based on PV battery-charging stations operated by local micro-entrepreneurs (ME) (project stage I). These ME bought the PV equipment via a (subsidized) credit, which they paid back with the money they charged consumers for charging their batteries. Thus the philosophy of the project is commercial and involves partial[177] repayment of the investment costs.

As a result of several problems (technical, organizational, informational), which led to non-payment of the fee, the delivery model was altered. The battery charging stations were transformed into individual SHS, while the ME model was maintained (project stage II). The concept was thus changed from the battery-recharging service to leasing of PV equipment. Between 1998 and 2002, 90 ME were created and around 2,700 households were electrified, with SHS benefiting 13,000 persons.

In 2002, after a case of fraud involving funds in another program, the foundation decided to terminate all project activities, including its pending responsibilities for the Luz do Sol program. Since then no new SHS have been installed. The withdrawal of FTV had severe consequences for the sustainability of the program. Today (May 2003), former FTV staff are trying to revive the project. They have created a new NGO, Instituto Eco Engenho, which has negotiated with FTV to assume responsibilities and continue project activities. Instituto Eco Engenho is studying the possibility of turning the leasing model into a fee-for-service model.

The following description and assessment will be limited to project stage II.

11.2.1 Description of the Delivery Model

The delivery model could be categorized as a **leasing model without ultimate purchase**.[178] However, the categorization in this particular case is not clear, since the way in which the delivery model is perceived differs from agent to agent and the information available is ambiguous. Many users and some authors[179] see the project as a service model, i.e. they understand the monthly fee as including not only rent for the SHS but also maintenance service and spare parts.

Financing

Investment costs were mainly financed through donations (channeled through FTV) and by a credit line of the Development Bank for Northeast Brazil (Banco do Nordeste – BN):

FTV succeeded in obtaining a good deal of imported equipment (such as PV panels, solar batteries and charge controllers) as donations from providers in the US.[180] This equipment was used originally for the battery charging stations (see above) and later for the SHS project. Aside from the function of raising funds (donations/grants) to finance part of the investment costs, FTV was also responsible for purchasing all of the equipment financed through BN credits (see below).

BN provided credits at favorable terms for the purchase of both imported equipment and local

176 This section is based on information gained during interviews with representatives of Instituto Eco Engenho (March 12 and 21, 2003), and with users and micro-entrepreneurs in the districts of São José da Tapera and Pão de Açúcar (March 17 and 18, 2003); Santos (2002); Ribeiro et al. (2002) and contractual documentation provided by Instituto Eco Engenho.

177 Part of the investment was financed via donations (see below).

178 See also Tables 6 and 7 for summarized description and assessment.

179 See Ribeiro et al. (2002), Annex 8.

180 PV panel providers: Golden Photon and Solarex. See Ribeiro et al. (2002), Annex 8; Santos (2002), Ch. 2.6.

components and material.[181] The credits were taken out by ME, who assumed responsibility for repayment and coverage of the related capital costs. The volume was sufficient for each ME to purchase 30 PVS.[182] The terms of credit were as follows: amortization within 12 years, a grace period of six months, interest rates around 9 % p.a.[183] The PV panels serve as security for BN until the overall credit has been repaid.

The ME used the BN money to purchase the 30 SHS from FTV and then rented them to consumers against a monthly fee of between R$ 12 and R$ 14, depending on credit volume and conditions.[184] Installation of the SHS was managed by FTV, which also took over installation costs (except for a modest installation charge of R$ 15 that was borne by the user – see below).[185]

As regards coverage of the **O&M costs**, there is no clear division of responsibilities. It is not clear if the monthly user fee includes the maintenance service or not.[186] FTV assumed the responsibility of providing maintenance service during the first year of the contract and agreed to bear the related costs (see below).

181 Whereas during the stage I BN only financed the purchase of local components and materials, during stage II BN financing also covered the imported equipment for the SHS. See Santos (2002), Ch. 2.6.1.

182 Financing up to this amount has the advantage that it can be approved by the local BN manager and allows for fiduciary guarantee only and is thus faster and cheaper to obtain. See Ribeiro et al. (2002), p. 22. It requires the ME to become a judicial person, though.

183 The interest rate depends on the market conditions at the time when the contract is signed. For more detail about credit conditions, see contract BN-FTV.

184 Since the PVS are imported, their price is heavily influenced by the exchange rate. Credit volume and thus monthly installments therefore vary from ME to ME, depending on the time when the contract was signed.

185 The installation firm charged R$ 1,500 for 30 systems plus installation material and transport. See Santos (2002), p. 85.

186 This issue is not specified, either in the contract between BN and ME or in the contract between BN and FTV.

Division of Responsibilities

FTV assumed a major role in the **marketing** stage. It identified project regions and selected ME. The criteria used for selection of a project region were the region's distance from the grid and the overall income of its inhabitants. The indicators used for income were agricultural production and percentage of pensioners (a high percentage of pensioners is considered an indicator for a high ability to pay, since pensioners have a regular monetary income).

The potential ME and customers in the target regions identified were informed about the project in meetings conducted by FTV staff. During these meetings the local population was given information about the possibility of acquiring an PV energy service, the technical potentials and limitations of SHS as well as the organization and the cost of service. One main objective of the meetings was to select ME and customers. FTV selected ME in accordance with the following criteria: interest in and motivation to start out in the business, entrepreneurial capacity (e.g. experience with some sort of local commerce, educational status, local leadership), sufficient potential customers (the candidates signed a list indicating their desire to acquire an SHS).

The ME identified were responsible for the final selection of customers and the collection of the monthly fees, which were to be used to cover repayment of the BN credit. The criteria used by the ME for client selection were: distance from the ME's residence, personal relationship and financial situation (the installation charge of R$ 15 was intended to select families with a sufficiently high ability to pay).

Once the selection was made, FTV helped the ME meet the requirements for a BN credit to purchase the SHS. This meant assuming the role of a judicial person and involved administrative tasks such as obtaining the ME's personal documentation, a non-debtor certificate, as well as registration with the tax authorities.[187] To complete the latter two tasks, more legal in nature, FTV contracted and paid an accountant. In addition, FTV monitored the financial arrangements, including the elaboration of a business plan (which was required by BN), down to and including signatures and credit payments.

FTV was also responsible for supplying and **installing** the SHS. The systems are the property of the ME who purchased them from FTV. Most installations were contracted out, not done by FTV staff.[188] Three different panel sizes (3*14 = 42 Wp, 43 Wp and 64 Wp) and two different battery sizes (48 Ah and 100 Ah) were used.[189] Regardless of panel size, the permitted load of the systems was 2 lamps, a radio, and a small black/white TV. The technician in charge of installation was responsible for informing the users about operation and maintenance procedures.

The users are responsible for the **operation** of the SHS and payment of the monthly fee. If a user fails to pay for two months, the ME has the right to deinstall the SHS. As mentioned above, responsibility for **maintenance** service and spare parts (especially the battery) is an unclear point, even though, according to the business plan, the delivery model is a leasing model, which means that the user is responsible for O&M. This lack of definition – which is one of the main weaknesses of the project (see below) – did not become apparent immediately, since for one year after installation, FTV assumed responsibility for having an employed technician provide maintenance and spare parts at its own expense.

FTV also assumed responsibility for **capacity-building and information** activities. These activities were conceived for both the users and the ME. First, information was provided during the initial meeting with the local population (see above). Second, user information regarding SHS maintenance and operation was provided during the installation of the systems. Some of the ME participated in installation activities in order to learn the installation and maintenance procedures. Third, information and training on O&M was provided to both users and ME during the regular visits of the FTV technician during the first year following installation.

Aside from technical training, FTV had committed itself to provide business administration training for the ME, if necessary. It appears that this task was not carried out systematically, and that the FTV technician provided no more than sporadic advice on business issues during his visits. The original idea was that, following an initial period of support by FTV, the ME would become self-sufficient and that a rising number of systems in use would give rise to a regional market for system components. The delivery model is illustrated in Figure 10.

11.2.2 Assessment of the Delivery Model

Financial Sustainability

When the field study was conducted (March 2003), the financial sustainability of the Luz do Sol project was under threat (the same is true for technical sustainability – see below). Under this model it is necessary to generate a cash flow that covers not only the O&M costs but part of the investment costs and capital costs as well (the repayment of the BN credits in this particular case). There are serious problems with coverage of the capital costs, as is indicated by the significant number of debtors (ME) that are not paying their installments to BN.[190]

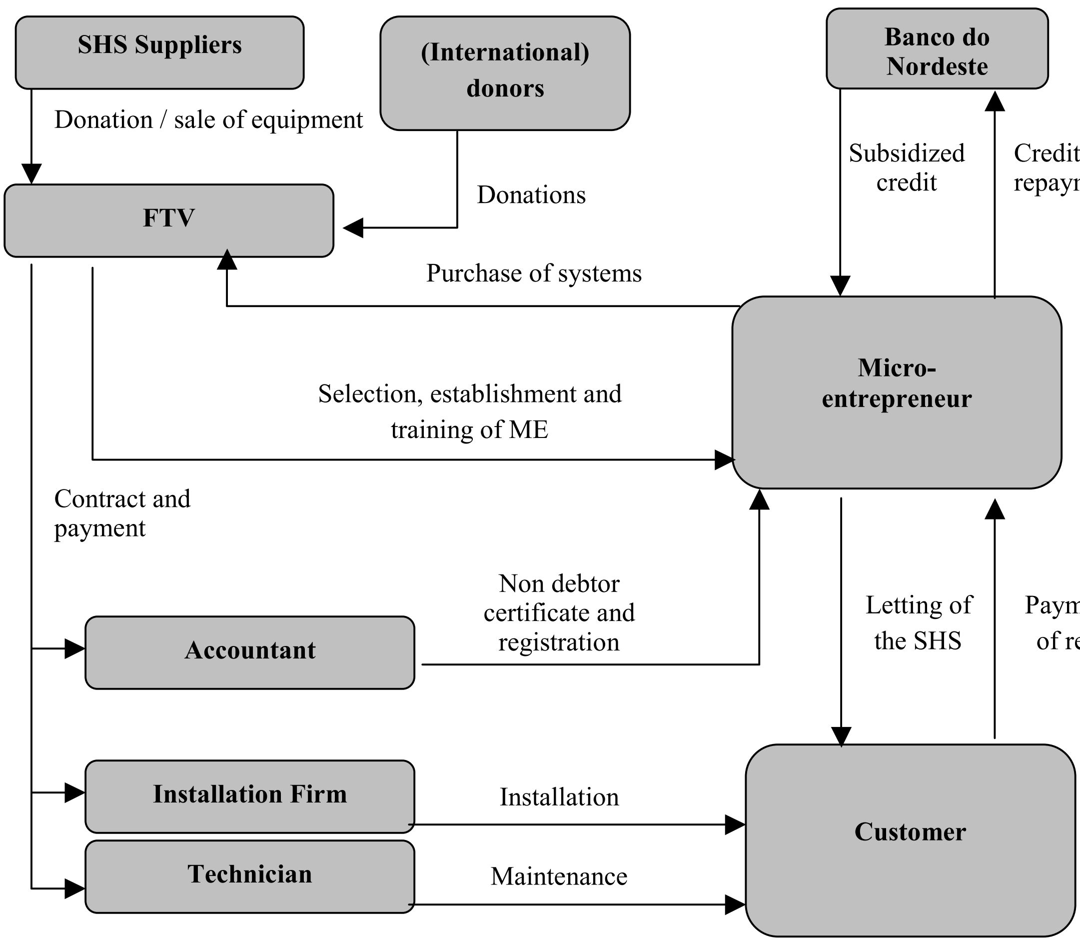
187 The so-called Cadastro Geral de Contribuintes (CGC).

188 Information gained during interview with representatives from Instituto Eco Engenho, March 12, 2003. See also Santos (2002), p. 80.

189 The 14 Wp panels (Golden Photon) and the 48 Ah batteries (Concorde) were a heritage of project stage I.

190 It was not possible to obtain any exact figures on current non-payment rates. Representatives of Instituto Eco Engenho described the share as “high.” They also informed us that BN was worried about the situation. It was confirmed that BN had started to take legal steps in order to recover the money from the ME. The three ME who were visited in the field were all at least one year

Figure 10: Delivery Model FTV



Source: Own illustration

The main reason for ME arrears is that many users have stopped paying their fees. This problem appears not to be rooted in a lack of customer ability to pay: while the systems worked satisfactorily thanks to maintenance provided by the FTV technician the rate of non-payment was low.[191] The problem seems instead to be rooted in a set of other factors: mal-definition of responsibilities for maintenance, persistent dependence on external maintenance skills, insufficient business administration skills (ME), and low-quality installations and system dimensioning (the latter two points are discussed in the section on technical sustainability). All these factors together had a strong negative impact on user willingness to pay and collection performance (enforceability of payments).

As noted above, the definition of arrangements between user and ME concerning responsibility for maintenance is vague. The problem is that in many cases neither of the two parties feels respon-

in arrear with their repayments. Information gained during interviews with representatives of Instituto Eco Engenho (March 12 and 21, 2003) as well as with users and micro-entrepreneurs (March 17 and 18, 2003).

191 According to Ribeiro et al. (2002), Annex 8, as long as systems were working well the rate of non-payment was 1.75 %. According to Santos (2002), by February 2001, 90 % of ME were up to date with their payments to BN.

sible for covering the maintenance costs, especially the costs for battery replacement.[192] A very important point is that the fee apparently was set too low to be able to cover maintenance service and purchase of spare parts.[193] This explains why ME usually have no interest in providing maintenance service. Since FTV covered the maintenance costs during the first year of the contract, this fact became evident only at the end of this "guarantee period." In order to overcome this conflict, FTV in many cases continued to provide maintenance service (and to cover the related costs) after the end of the first year.[194] The conflict escalated when FTV retired from the project in 2002, and many users stopped making their payments, pointing to technical problems. The situation was exacerbated by technical weaknesses that led to relatively high failure rates (see below).

One reason for the inadequate definition of responsibilities seems to be FTV's information policy. Both ME and users were informed about the project and all its implications during a general meeting. There were no "specialized" follow-up meetings for the ME only, which might have served to prevent confusion about tasks and responsibilities.[195] As a result of the deficient and in some cases even misleading[196] information provided, there were differences in the way the agents understood their maintenance responsibilities.

Another source of bad collection performance seem to be a lack of business administration skills as well as the weak legitimacy and authority of many ME:

Many ME appeared not to fully comprehend the scope of the financial transactions they were to engage in. To improve this situation, one FTV technician handed out blank receipts. These were well accepted by users, who considered them as an official document on their payment, but apparently they were not used by the ME for bookkeeping purposes. Some ME did not keep books at all and thus did not know whether they were earning or loosing money.[197]

Another weakness is the fact that many ME do not have enough legitimacy and authority to use sanctions to enforce fee payments (e.g. deinstallation of the PV panel). One reason for this is the relatively bad technical performance of many systems (see below). Other reasons appear to be close relationships to customers, which constitutes an obstacle to the use of sanctions. In remote and poor areas non-payment penalties generally appear to be difficult to enforce for reasons of solidarity. Many ME felt they lacked authority to enforce penalties and preferred to wait for the FTV staff to do so. In addition, the credibility of the ME is not high: users usually stopped making payments when the ME ran out of "official" receipts (see above) and refused to accept improvised receipts offered by the ME.

As regards ability to pay, it can be noted positively that the approach was apparently successful in selecting regions or customers with incomes sufficiently high to cover the monthly fees (12 to 14 R$). This can be inferred from the fact that non-payment rates were low, while technical performance was good, which means that user satis-

192 There are also success stories of ME who have taken responsibility and provided adequate maintenance service in order to continue obtaining fees from the users.

193 See Santos (2002), p. 87.

194 It can be argued that financial sustainability was at risk even during this period since FTV relied on sporadic donations from the Interamerican Development Bank, PRODEEM, or other donors and thus lacked the constant inflow of resources that would have been necessary to ensure the financing of the maintenance costs.

195 Apparently, the responsibilities of the ME were described as merely collecting fees and handing the money over to the bank. Thus ME were surprised to find that there could be problems evolving, and they were often unprepared and overstrained.

196 One member of the FTV staff explicitly told the locals that FTV would cover all maintenance costs, not making it clear that this only was true for the first year. Information gained during an interview with a representative from Instituto Eco Engenho, March 21, 2003.

197 Information gained during interview with ME in the district of Pão de Açúcar, March 18, 2003.

faction was high (see above). This is remarkable in view of the fact that fees are rather high compared to other PV projects.

Technical Sustainability

Aside from the vague definition of maintenance responsibilities, low-quality installation and dimensioning as well as persistent dependence on external maintenance skills are the major threats to technical sustainability. When the field study was conducted (March 2003), a considerable percentage of the SHS were not working and many systems were being operated without a charge controller.[198]

Looking at the quality of installation and components, early battery and ballast failure are the most evident problem. The batteries that had already been used in the battery loading station project were deficient (these were the 48 Ah Concorde batteries). Even most of the "new" Concorde batteries started out with reduced capacity, since they had been stored for too long.[199]

Apart from this, systems were apparently not adequately dimensioned. The 48 Ah batteries are considered too small to ensure proper system operation, taking into account the factors of permitted load and use patterns. To make more use of the system, electricity was used during the day, and charge controllers were bypassed. The result was overusage and even earlier battery failure, since batteries could not recharge properly. Local technicians reported that more than 40 % of users were "bad clients" in the sense that they were overusing the system.[200] FTV reacted by replacing the deficient batteries with new ones of higher capacity.

As far as maintenance is concerned, many ME projects did not reach self-sufficiency and continued to depend on FTV's maintenance service. The concept of continued learning during every visit of the FTV technician (first year of contract) as well as decentralized maintenance by the ME are an interesting approach for reducing transaction costs[201] and enhancing technical sustainability. However, in practice this did not work out quite as well as expected:

Users and ME were informed about usage and maintenance during the first general meeting. According to our user interviews, the more hands-on instructions that were to be given during installation failed to materialize, especially in cases in which the installation was contracted out.

As far as the regular training provided during maintenance is concerned, it appears that the FTV technician was very often not overly interested in instructing users, since it was of course easier and faster to simply check the equipment and carry out repairs. This may be due to the fact that the project grew rapidly and the number of SHS and communities to be served by one technician became so large that it was no longer possible to solve problems in a reasonable period of time. Also, users were not given information material (handbook, leaflet, or the like) for reference purposes or to remind them of their duties and explain correct use. As a result, both users and ME were poorly informed about use and small repairs of the systems.[202] According to Santos,[203] less than 60 % of ME were able to carry out some basic maintenance tasks. The others remained completely dependent on the FTV technician.

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198 Of the three ME visited, two reported a share of above 50 % of non-operational systems (one ME reported a share of 7 %). The majority of the systems in operation were operated without charge controller. Information gained during interviews with users and micro-entrepreneurs on March 17 and 18, 2003.

199 The batteries date back to 1995. These batteries did not reach their average lifespan of 3-5 years (see Ch. 3.2), on average failing much earlier.

200 See Santos (2002), pp. 84-86.

201 Transport accounts for the largest part of maintenance costs.

202 As one ME said, "what I know about the systems I had to figure out myself." Information gained during an interview with a ME in the district of São José da Tapera, March 17, 2003.

203 See Santos (2002), p. 86.

It can be noted positively that a market for spare parts developed in Santana de Ipanema, where 20W ballast were sold for R$ 13, the prices for lamps and electric appliances such as 12V blenders being R$ 4 and R$ 50, respectively.[204] For a model based on local maintenance this is a factor of special importance.

Other Factors

The FTV approach shows that fees in the range of 12 to 14 R$ a month are affordable for a segment of the rural target population (non-payment rates were low while the systems were working well). However, this monthly fee appears to be too high for the poorest segments of the target group. In addition, it has to be kept in mind that the fee does not include maintenance costs and the monthly expenditure needed to cover all costs are actually even higher.

The Luz do Sol program is not adequately coordinated with the grid extension plans of the concessionaire of the state of Alagoas (CEAL). Today low voltage lines run less than a kilometer from some of the houses visited. Even though households have no reason to believe that they can be connected easily to the grid, satisfaction with and willingness to pay for PVS electricity decline in view of the prospect of obtaining grid electricity. Local politicians promise to cover grid connection costs in exchange for the votes of the rural population.[205]

204 Santos (2002), p. 86.

205 Information gained during interviews with users and micro-entrepreneurs (March 17 and 18, 2003).

11.3 The Program Produzir of CAR in Bahia[206]

CAR (Companhia de Desenvolvimento e Ação Regional), a company linked to the Bahian State Secretary of Planning, Science and Technology (SEPLANTEC), coordinates the Produzir program, the aim of which is to increase the quality of life of poor rural communities in Bahia by carrying out infrastructure and social projects. Aside from its central office in Salvador, CAR has 17 regional offices to support its work in 406 districts. The program's design places emphasis on participation of the target group in decision-making and the implementation of projects. For this purpose, it works together with local associations in the program region. These local associations may, for instance, be made up of small farmers, fishermen, craftsmen, women etc.

Rural electrification via PVS is one element of Produzir's subprogram directed at physical infrastructure. Partners are predominantly rural associations of small farmers. Between 1998 and the end of 2002, the program had financed more than 14,000, mainly residential, PVS.[207] It is estimated that the total capacity installed sums up to more than 3,000 kW and benefits around 66,700 persons in 215 communities, located mainly in the poor and sparsely populated *Sertão*.[208] This means that CAR/Produzir is by far the most important

206 This section is based on information gained during interviews with CAR representatives, representatives of rural associations and users (Salvador: February 18, 2003, district of Serrinha: March 6, 2003, district of Arací: March 7, 2003, Euclides da Cunha and district of Canudos: March 10, 2003); Pereira/ Reis/ Figueiredo (2002); Oliva (2002); Fontoura (2002); CAR (2002a-d).

207 CAR estimates that about 1,000 PVS are community systems (basically in school buildings, churches and community centers). See Pereira/ Reis/ Figueiredo (2002).

208 See Oliva (2002), p. 75, and Pereira/ Reis/ Figueiredo (2002). The number of benefited persons (66,700) is calculated by taking the number of the installed residential PVS in November 2002 (14,344) by the number of persons of an average family (5) thus excluding community PVS.

single program for the dissemination of PVS in Brazil.

11.3.1 Description of the Delivery Model

The delivery model can be labeled as a **community-based service model**.[209]

Financing

Because of its social and welfare objectives, Produzir has a very high subsidy element, and thus cost recovery plays a role only for the O&M costs of the projects approved.

The program is financed jointly by the World Bank (in the framework of its Poverty Alleviation Program) and the State Government of Bahia. A typical PVS project financed by CAR consists of about 48 residential systems (SHS) and one community system. 90 % (usually up to 85,000 R$) of a project's **investment costs** are provided in the form of grants. These resources come from the general revenues of the State Government of Bahia and from a World Bank credit. The state government of Bahia has assumed the entire responsibility for repayment of the credit.[210] The remaining 10 % of the investment costs are borne by the rural associations who receive the systems. Participation of rural associations usually consists in a non-financial contribution in form of labor, construction materials, and administrative assistance.

CAR does not finance **O&M costs** and they therefore have to be borne by the users. To guarantee the sustainability of the projects, the local associations are supposed to create and administrate a maintenance fund fed by regular user payments. At present, creation of a maintenance fund is not compulsory, but in the future CAR intends to turn the maintenance fund into an obligatory element of the contract with the associations/ municipalities. To cover the O&M costs of the individual SHS, CAR actually recommends a monthly fee of 9.50 R$.

Division of Responsibilities

The **marketing** is a joint process involving CAR, the local association, and an institution called the municipal council (*conselho municipal*).[211] The project allocation process is intended to be a bottom-up approach in which the local associations direct their requests for a solar energy project either directly to CAR or via the intermediation of the municipal council.[212] CAR has defined the following criteria for selecting beneficiary communities:[213]

- Strong organizational capacity of the local association
- Minimum distance of 10km to the central grid and high dispersion of the residents' homes
- Use of traditional energy sources like diesel, kerosene, liquid gas for illumination

During the interviews it was mentioned that besides these formal criteria for the allocation of a PVS project, political considerations (e.g. the preferences of the leadership of the rural associations for a political party) are also important for approval of a project request.

In all three communities local demand for SHS was greater than the number of systems financed by the

209 See also Tables 6 and 7 for summarized description and assessment.

210 See Pereira/ Reis/ Figueiredo (2002).

211 The municipal councils coordinate the activities within the program Produzir at the local level. The composition of the municipal councils is: 80 % community representatives (local associations, rural worker unions), 20 % representatives of the local authorities (mayor, councilors) and civil society (church, charity clubs). See CAR (2002b).

212 This depends on the program modality. Under the PAC modality (*Programa de Apoio Comunitário*), the rural association directs the request directly to CAR. Under the FUMAC modality (*Fundo Municipal de Apoio Comunitário*), the municipal council collects the project demands, discusses them and elaborates a priority list that is forwarded to CAR. See CAR (2002b).

213 See CAR (2002a).

project. However, according to the presidents of the local associations there have been no problems with selecting the first beneficiary families. Priority is always given to community systems, then to the closest members of the associations living more than 10 km from the central grid, then to more distant houses and persons who are not affiliated with the association.

The participatory structure of Produzir permits the associations to select a local firm for the supply and the **installation** of the PVS on the basis of an invitation to tender, reviewing at least three cost proposals based on the technical standards defined by CAR. The firm with the lowest cost proposal has to be chosen. Due to problems with bad installations in the past, CAR recently stipulated that the winner firm has to present a special license (ART – *Anotação de Responsabilidade Técnica*) and the certification number (CREA – *Conselho Regional de Engenheiros e Arquitetos*) of the responsible engineer. The final installations are inspected by a CAR employee.

The SHS become the property of the association. Thus, if a user leaves the region, she has to return the system to the association, which then can pass it on to another association member.[214]

The users of the CAR-financed PVS projects cannot choose between different system sizes. In its project manual CAR defines a standard kit for SHS. The residential systems consist of 1 solar panel of 50Wp, 1 charge controller, 1 battery (115 Ah/12 V), 4 fluorescent lamps with ballast (9 W/12 V), 2 plugs with direct current (DC) for the connection of a radio and a black-and-white TV.[215]

The division of responsibilities for **maintenance** between the installation firm, the association, and the users is clearly defined by CAR in the following way:[216]

Installation firm:
- Corrective maintenance of all components during the guarantee period
- Technical assistance (visits every 4 months) during the first year
- Replacement of old batteries, with a refund of 10 % for purchase of a new one
- Technical instruction for users (explanation and manual)
- Training of two members of the association, who are responsible for routine and preventive maintenance[217]

Rural association:
- Formation of a commission for the management and operation of the PVS
- Creation of a maintenance fund for corrective and routine maintenance after the guarantee period
- Guarantee of routine maintenance
- Monitoring of maintenance and operation

Users:
- Definition and payment of contributions to maintenance fund
- Preventive maintenance.

To formalize these responsibilities, CAR has developed two standard contracts: one between the association and the installation firm and one between the association and the user (*termo de cessão*).[218]

Capacity-building and information activities are a shared responsibility. At a general meeting with association members following project approval, a technician from the installation firm, together with a CAR employee, provide user information about

214 To clarify ownership relations, CAR has defined a standard contract between the association and the user called *termo de cessão*. See CAR (2002a), p. 36.

215 See CAR (2002a). The community system includes 3 Solar panels of 50Wp (=150Wp), 1 charge controller, 2 batteries (115 Ah/12 V), 4 fluorescent lamps with ballast (9 W/12 V) and 2 fluorescent lamps with ballast (11W/12V), 2 plugs - alternate current (AC), an inverter DC/AC 12V-115/220V, a color TV, a satellite receiver, and a VCR.

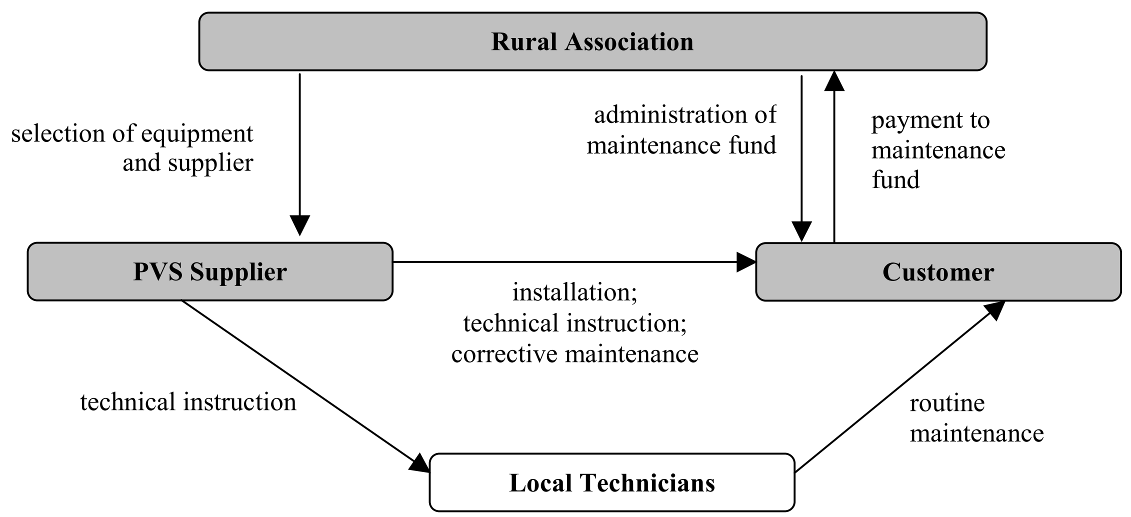
216 See CAR (2002a).

217 See standard contract between association and installation firm.

218 See CAR (2002a).

the technical features of the SHS, the organizational model, and the costs involved. The installation firm is required to provide the individual user information on use etc. and to hand out a short manual during the installation of the SHS. Aside from this, the installation firm trains two association members who will be in charge of the routine maintenance (e.g. replacement of ballast, lamps, and batteries).

Figure 11: Delivery Model CAR



Source: Own illustration

With a view to monitoring the quality of the installation and PVS components, CAR has placed emphasis on the capacity-building of its own staff. In consequence, 17 CAR technicians were trained by the NGO Winrock in 2002.

The delivery model set out above is illustrated by Figure 11.

11.3.2 Assessment of the Delivery Model

One problem involved in drawing conclusions about the performance of the CAR delivery model and thus on the financial and technical sustainability is that none of the three projects visited was older than three years. The PVS were still functioning relatively well and without need for maintenance because most of the components had not yet reached the end of their lifespan. Expensive parts, especially the battery, had therefore not yet needed to be replaced. In consequence, the users were in general very satisfied with their systems and the overall project management. But it is very likely that there are still some challenges to come as soon as the first major maintenance problems occur.

Financial Sustainability

Since the SHS are a donation by CAR, the minimum requirement for financial sustainability is coverage of the O&M costs through user contributions.[219] Creation of a maintenance fund, proper administration of the fund, and definition of a sufficiently high regular contribution (CAR recommends 9.50 R$ per month) appear to be espe-

219 Sustainability problems concerning the burden for the budget of the state of Bahia that results from assuming responsibility for covering the investment and capital costs are not addressed here.

cially important to attaining financial sustainability.

As stated above, it is difficult to draw any general conclusions on the CAR program as a whole.[220] However, it appears that financial sustainability is at risk in many projects.[221] A common problem is that maintenance funds either are not created or monthly contributions are too low. In this case it is likely that many users will be unable to finance replacements for expensive components (especially batteries), which means that the systems will no longer work. Lack of funds also encourages both purchases of low-quality components and improvised solutions which compromise financial (higher life-cycle costs) and technical sustainability (see below).

Since the local association is responsible for the creation and administration of the maintenance fund (including collection), the financial sustainability of projects depends to a large degree on local organizational capacities and on the dedication of local leaders (the same is true for technical sustainability). Comparison of the three communities visited supports this hypothesis:

The association of Nazaré (district of Arací), which can be seen as a model case in reference to its overall organizational and administrative capacity and its active president, was also the only community that had implemented a sustainable maintenance fund based on a monthly payment of 5 R$.[222] In Nazaré payments flow into a common maintenance fund, but the association also controls the individual accumulated payments of each user to avoid moral hazard and to stimulate users to treat the SHS in such a way as to maximize the lifespan of the components. So far, the fund has been able to cover all O&M costs due to replacement of components. As mentioned above, maintenance has been limited so far because of the brief existence of the projects. Once batteries have to be replaced, the fund's resources may quickly be depleted. Users seemed to be informed about maintenance costs.

The association in Umbuzerão (district of Canudos) decided to create a maintenance fund based on a fee of 3R$ /month, but it appeared that the rather weak association and the lack of a responsible local person has led to problems with the payment collection: no payments have been collected since the installation of the systems (seven months before the visit). There are plans, though, to start up a maintenance fund after one year, when the initial guarantee by the installation firm ends. Users were not very well aware of maintenance costs.

In Saquinho (district of Serrinha), no maintenance fund was created, although the association and its president seemed to be committed. After 3 years, 3 of 21 PVS were not functioning because the families had no money to buy new batteries. This was partially due to lack of user information about maintenance costs. One possible explanation of the absence of a maintenance fund in this case is the fact that the president of the rural association intended to run for the council in the next elections and thus might have preferred to be perceived as a "benefactor" rather than as a "fee collector."

Technical Sustainability

The PVS projects under the Produzir program have had a lot of problems with the quality of past installations. Earlier evaluations observed installations with missing charge controllers, loose cables, and inadequate batteries.[223] In contrast to these observations, the installations of the SHS in the three communities visited were of relatively good quality. The systems that were looked at had a charge controller fixed in a box on the wall, the

220 Besides the reasons given above, the number of cases visited (28) is small in comparison to the total number of PVS installed under the Produzir program (14,000!).

221 See Fontoura (2002), Ch. 6 for another assessment of CAR with similar results.

222 Since the association members pay an administrative fee of 1R$/month, the total monthly payment sums up to 6R$. See also Fontoura (2002), p. 59.

223 See Fontoura (2002).

cables were protected and properly fixed, and the batteries seemed to be of good quality and were located in a protection box. This may be a sign that CAR is going through a learning process and that the new requirements for installation firms as well as stricter monitoring procedures are having positive effects on the quality of installation.

Problems due to low component quality mostly affected the lamps and the ballast. Once informed, the installation firms changed to another brand for these products.

In the three communities visited, the majority of users knew at least one local person who was trained by the installation firm to take care of maintenance for small problems. This person usually lived nearby and could therefore be informed easily. But his qualification was generally limited to simple tasks like changing lamps and ballasts. More qualified technical assistance is usually available through the installation firm. However, after the end of the one-year guarantee period these costs have to be borne by the users. In associations that have not created a maintenance fund, users may be reluctant to bear these costs and may prefer improvised low-quality solutions, compromising the sustainability of their systems.

In general, the information users had about the capacity and the handling of the SHS was very basic. There appears to be room for improvement in this area. One problem is that many persons simply forget the information given to them. It would be better to repeat the instructions at periodic intervals.

Another problem found was that some components were not available in the local market (the closest town). Thus the users or the local person responsible for maintenance had to travel quite long distances to buy components needed.[224]

224 More than 70 km in one case (from Nazaré to Feira de Santana).

Other Factors

The CAR delivery model assigns great responsibility to the local association. Thus it is not surprising that performance varies according to the individual association's degree of organization and management capacity. It appears that the relevant formal selection criteria for project allocation (strong organizational capacity of the local association; see above) are not operational as we found examples for poorly developed local capacities.

The emphasis placed on participatory elements in the project design is a positive aspect. However, this may be supplanted by the clientelistic strategies that are quite common in projects with a high state-financed subsidy element.[225] The objective of some political actors, to use CAR projects to gain votes, may lead to neglect of the primary project target, i.e. to provide sustainable electricity services to poor and dispersed rural households.

The fact that only O&M costs have to be borne by the users increases affordability for poor households. However, there is a danger that willingness to pay may be compromised by a lack of ownership and commitment due to the fact that the SHS are seen primarily as a gift. This danger is especially high when SHS projects are used as part of a clientelistic strategy.

Just as in the case of the previous two delivery models, the CAR program lacks coordination with the grid extension of the regional concession holder (COELBA). In the case of the project in Saquinho (district of Serrinha), the grid reached the area just two years after the installation of the PVS. It was, though, possible to avoid a misallocation of resources by transferring the SHS concerned to association members who lived further away form the grid.

225 See also Ch. 9.4.

11.4 The Luz Solar Rural Pre-electrification Program of CEMIG in Minas Gerais[226]

CEMIG (Companhia Energética de Minas Gerais), the energy company of the state Minas Gerais, holds the concession for 98 % of the state, with almost 5 million consumers. As a concessionaire of public services, the company has to respect the existing regulations concerning the provision of energy.[227] CEMIG is a stock corporation. The government of Minas Gerais – which holds the majority of the shares – has committed the utility to focus on social issues, especially rapid universalization of electric service. In fact, there are approximately 120,000 rural households without electricity in the state of Minas Gerais (the rural electrification rate is 80.3 %). The state government target is to reach full electricity coverage by the end of the year 2007.

CEMIG has been testing the use of solar energy for rural electrification since 1986. Since then it has carried out various pilot projects with different philosophies and delivery models.[228] The most important of these projects is the Luz Solar pre-electrification program.

Luz Solar was begun in 1999 as a subprogram of the Lumiar rural electrification program; its goal was to pre-electrify[229] 5,000 rural households and 500 public buildings in the north and east of the state with PVS. By the end of 2002 509 residential SHS and 546 community systems had been installed. So far, Luz Solar has served as a demonstration program to test the technical and financial sustainability of PVS for the company, and it has still rather the character of a voluntary social project. On the basis of the experience made, CEMIG is now working on integration of the PV technology in the company's formal service structure in order to overcome the demonstration character of PV activities as well as to mainstream them. However, the existing regulatory uncertainties concerning off-grid PVS,[230] problems with the sustainability of the program, and some resistance within the utility are serving to complicate the mainstreaming of this technology.

The following section will focus on deployment of residential systems (SHS).

11.4.1 Description of the Delivery Model

The delivery model can be categorized as a **utility-based service model** in a regulated-market framework.[231]

Financing

The conditions for the financing of the **investments** for Luz Solar were defined by the general conditions of the Lumiar program (which also applied for grid electrification). As a general rule, the burden of investment and capital costs was shared by CEMIG and the local municipality (or, in exceptional cases, by a local communal association). The amount borne by CEMIG depends on the socioeconomic condition of the municipal-

226 This section is based on information gained during interviews with representatives of CEMIG (March 31 to April 4, 2003), with representatives from the municipality of Diamantina (April 2, 2003), with users in the district of Diamantina (April 3 to April 4, 2003), and with a representative of Instituto Pro-Cittá (April 5); Santos (2002), Diniz (2000) as well as further documents provided by CEMIG and GTZ/CEMIG (project *Uso Racional de Energia na Agricultura*).

227 See Ch. 9.

228 One of them (a community-based service model) was implemented as a subproject of the joint CEMIG/GTZ project *Uso Racional de Energia na Agricultura*. See Box 7. See Diniz (2000), Santos (2002), Ch. 2.4.1, and IEA (2002), Annex A, for a description of previous CEMIG delivery models for PVS electrification.

229 In the first stage of Luz Solar, the use of PVS was seen as pre-electrification, i.e. as a first stage of electricity supply prior to connection of the consumer to the grid. Today, CEMIG assumes that in some cases electrification with PVS will be definitive.

230 See Ch. 9.3.

231 See also Tables 6 and 7 for summarized description and assessment.

ity in question.[232] On average, 64 % of investment costs were covered by CEMIG. The remaining 36 % was borne by the municipalities (or local associations).[233]

The resources needed to finance the investment costs covered by CEMIG came from various sources; two of these with significant grant elements will be highlighted here: a CEMIG fund fed by 5 % of the annual profit of the company and dedicated to the electrification of low-income households and a interest-differential fund resulting from a loan granted by KfW.

At the moment, CEMIG bears the whole of **O&M costs,** and users are not charged any fees because of the existing uncertainty concerning the legal framework. In one of the delivery models tested during the first stage of Luz Solar, CEMIG intended to make the users responsible for covering maintenance costs. The community benefited was supposed to create and administrate a maintenance fund by collecting a fixed fee from users to cover maintenance costs and replacement of faulty components (this is similar to the CAR delivery model). However, because of problems with this division of responsibilities and the quality of maintenance, CEMIG assumed overall responsibility for maintenance in the Luz Solar program.

In the more or less near future the intention is to charge users the regulated tariff for low-income households of about 2 R$ per month in keeping with the costs borne by grid-connected clients. Charging the regulated tariff requires PVS clients to be integrated into the company's formal registration and accounting system for purposes of billing.

232 All municipalities of the concession area are divided in three classes (A, B, C) depending on share of poor households and living conditions (A is the class with the highest share of poor households). CEMIG bears the following amounts per SHS: Class A: R$ 1,300, class B: R$ 1,100, class C: R$ 800.

233 See Santos (2002), p. 59.

Division of Responsibilities

The **marketing** of the PVS is handled with the help of the local business agents of CEMIG based in regional business centers. The agents contact the local municipality (local association), demonstrate the technology and collect information about demand. For this purpose a general meeting with future SHS users is held; the meeting is chaired by a CEMIG technician who explains the relevant features of the systems and distributes information leaflets. Once agreement has been reached on financial issues and a division of responsibilities, the contract is signed by the municipality and CEMIG.

CEMIG has defined the following selection criteria for communities to be electrified with PVS:[234]

- The community must be located at a minimum distance of 5 km from the central grid and be more or less highly dispersed.
- The community may not be included in the company's grid connection plans for the coming 5 years.
- Adequate conditions must be given for acceptance of the technology as well as for the routines involved in operation, maintenance, and monitoring.

Since the municipality bears part of the investment costs, it may be assumed that the choice of communities to benefit from the PVS project may also be influenced, at least in part, by clientelistic motivations.

The PVS **installation** process is either handled by CEMIG or outsourced to an installation firm monitored by CEMIG. For this purpose CEMIG has elaborated specific procedures and manuals[235] aimed at ensuring quality. The installation firm is selected on the basis of a tender and the firm's technicians are professionally trained by CEMIG. Afterwards, the quality of installation and components is checked by CEMIG technicians. The

234 See Santos (2002), p. 45; Diniz (2000), p. 12.

235 See CEMIG (2000a) and (2000b).

overall system – except domestic installations – becomes the property of CEMIG.[236]

There are two standard system sizes for residential clients: i) 1 solar panel of 50 Wp, 1 charge controller of 10 A, 1 battery of 110 Ah. The permitted loads are 3 to 4 lamps (20W each) and a radio. ii) 1 solar panel of 100 Wp, 1 charge controller of 10 A, 1 battery of 220 Ah. The system is suited for the operation of 4 to 5 lamps (20W each), a radio and a black & white TV.[237] Recently, CEMIG has decided to equip all systems with an DC/AC inverter in order to avoid ballast failure (see below). This makes it possible to use AC loads.

Due to the demonstration character of Luz Solar, the division of responsibilities related to **maintenance** has changed in the course of the project. In the first stage, CEMIG intended to decentralize responsibility for the maintenance of the PVS and to outsource it to trained local persons. But this delivery model has not been implemented because of organizational problems and legal uncertainty. On the one hand, it became obvious that it would not be possible to ensure the desired quality standards, in spite of the training efforts. On the other hand, bad or deficient organization of the maintenance fund has led to financing problems.[238] Thus, at the moment, CEMIG has temporarily taken over the responsibilities for all types of maintenance and is planning the following division of responsibilities for the future:

There are plans to define an *entry point* similar to the central grid. The entry point would be located on the user side of the battery or the DC/AC inverter, if applicable. In this way, the user would be responsible for all parts beyond the entry point – e.g. for lamps, cables, plugs, etc. CEMIG, on the other hand, would take over responsibility for the maintenance of all parts up to the entry point (from the panel to the battery or the DC/AC inverter, if applicable – these are the components that remain the property of CEMIG). In cases of failure, PVS users can contact the service center (Central de Atendimento aos Consumidores) in much the same way as grid-connected clients. The maintenance model is centralized. This means that maintenance is provided by regular CEMIG technical staff (which is also responsible for the grid), based at the closest regional maintenance center. The technical staff is linked with the service center by a mobile communication system. To ensure that preventive maintenance is carried out and to assist users in the operation of the SHS, the municipality (or local association) will specify a local person to be trained by CEMIG.

As before, CEMIG will be responsible for **capacity-building and information** of all relevant agents. For technician capacity–building, CEMIG set up a special training department for solar energy in the company-owned training center EFAP (Escola de Formação e Aperfeiçoamento Profissional) in the city of Sete Lagoas. The center offers courses for installation and maintenance as well as for auditing and quality control of the PVS.[239] Besides their own technicians and those of the licensed installation firms, local persons from the benefiting municipalities are trained to do preventive maintenance.

The CEMIG technicians are responsible for instructing users concerning the handling and the capacity of their systems. This is usually done at a special community meeting held prior to installation of the SHS as well as during the installation of the systems. CEMIG has developed especially adapted information leaflets (ion comic-strip form) and a user information videotape. The PVS of the local school usually is installed prior to the residential systems. In this way future users (especially children) have a chance to get used to the technology and learn about maintenance procedures.

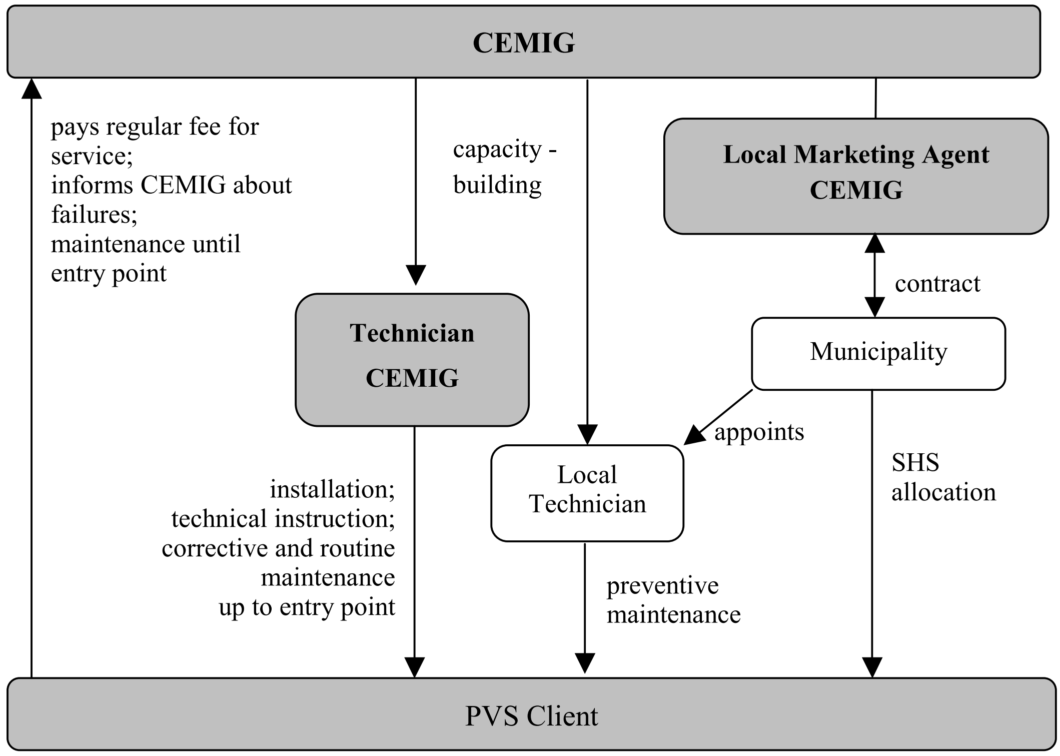
236 In some cases this is a controversial point between CEMIG and the municipalities, since the municipalities bear part of the investment costs.

237 Recently a third residential system size (300 Wp) has been introduced. The community systems are adapted to local demand, selecting one of 4 defined standard kits (from 300Wp to 1,000Wp).

238 See also Santos (2002), p. 56.

239 See also training materials CEMIG (2002a) and (2000b).

Figure 12: Delivery Model CEMIG



Source: Own illustration

Figure 12 illustrates the future delivery model of CEMIG based on the definition of an entry point.

11.4.2 Assessment of the Delivery Model

Financial Sustainability

Viewed in terms of the sustainability criterion chosen (coverage of O&M costs by user contributions), the Luz Solar program has to be judged as financially unsustainable. Luz Solar generates costs for CEMIG but has, up to now, generated no income. Even if CEMIG started to charge the regulated tariff for low-income households of about 2 R$ per month, this judgment would still stand, since the fee would come nowhere near covering O&M costs. The estimated maintenance costs are much higher (between 17 and 21 R$ per month).[240] The relative high maintenance costs are partially due to the option for a centralized maintenance model which implies high transportation and labor costs for the professionally trained CEMIG technicians (see above). The reasons why CEMIG has been able to implement Luz Solar up to now, in spite of this unfavorable financial performance, is the utility's privileged access to funds with a high grant element and its commitment to the social goals formulated by the state government of Minas Gerais. However, to ensure finan-

240 Real O&M costs are not easy to determine, because of a lack of experience at present. One visit of a CEMIG technician costs approximately 200 R$ (information gained during an interview with CEMIG representatives on March 31, 2003). If one visit per year is assumed, this amounts to about 17 R$ per month. COELBA (the concession holder for the state of Bahia) estimates that the O&M costs for SHS are about 21 R$ per month (information gained during an interview with a representative from COELBA on February 19, 2003).

cial sustainability more attention should be paid to cost recovery.

In contrast to the other three delivery models investigated – where the upper limit of user charges is mainly determined by user ability and willingness to pay – in the case of CEMIG this limit is set by sector regulation. Although there are still doubts as to whether the tariff regulation for low-income households applies for PVS and whether PVS-based supply will be accepted as a legal approach for universalization of public electricity supply, this scenario is a likely one.[241] Anticipating developments of the regulatory framework, CEMIG plans to make no distinction between PVS and grid energy supply and to charge the tariff for low-income households as soon as possible.

By charging the tariff for low-income households and integrating the PVS clients into the formal registration and accounting system, it would be possible to claim full costs for the provision of rural households with solar energy during the next tariff revision by ANEEL, and this would allow CEMIG to increase the average tariff level for all 5 million electricity consumers in order to cover the financial losses resulting from PVS supply. Exactly this cross-subsidization mechanism is already in use for rural grid electrification, which shows similar financial losses in areas with low consumption density.[242]

In view of this state of affairs, it is justifiable to reformulate the financial sustainability criterion, used in the present study, for the case of a regulated-market approach. The minimum requirement for financial sustainability was defined as coverage of project O&M costs by user contributions. However, ANEEL applies a different sustainability criterion for the regulation of Brazilian concessionaires, the so called *equilibrio econômico-financeiro*:[243] ANEEL looks not at the cash flow of an individual investment project or program (such as Luz Solar) but at the cash flow resulting from the activities of the utility in the overall concession area. The criterion of *equilibrio econômico-financeiro* is met when costs (including an adequate profit rate) and income at the concession area level are balanced. This alternative financial sustainability criterion allows for cross-subsidization of rural consumers by other consumer classes. Since the aim of the *equilibrio econômico-financeiro* is to evaluate the financial sustainability of the concessionaires' activities, and since this is the relevant criterion applied in regulating the Brazilian electricity sector, it seems justifiable to take it into consideration in evaluating off-grid PVS activities.

Assessment of the impact of the Luz Solar program on the *equilibrio econômico-financeiro* of CEMIG goes far beyond the scope of the present study. Besides, this impact is hard to assess because of the existing regulatory uncertainties concerning the implementation of universalization (via PVS). The impact will depend to a high degree on the availability of and the conditions for financial resources from sectoral funds like CDE and RGR.[244] Nevertheless, the experiences from the other delivery models investigated (11.1. to 11. 3) suggest that there is room for increasing the tariff for low-income households (presently around 2 R$ per month). This would reduce stress on financial sustainability in a possible future regulated-market delivery model.

As far as expected future collection performance is concerned, it may be assumed that the existing infrastructure and client confidence in the institution will facilitate the collection of a regular fee set out in an official electricity bill. However, the fact that CEMIG has not collected any contributions from users until now might lead to difficulties in enforcing fee collection in existing projects: the interviews showed that many users were

241 See Ch. 9.3.

242 Further research is necessary to gain more reliable information on the comparative lifespan costs of grid and PVS electrification for the specific Brazilian conditions.

243 See Fonseca (2002) and Ribeiro (2002), Ch. 2.4 for a explanation of the *equilibrio econômico-financeiro*.

244 See Ch. 9.3.

not aware that CEMIG intended to charge a fee in the future. Moreover, several users mentioned as an important advantage the fact that their SHS was free of charge. Apart from this, it is not even certain whether the present low-income tariff of 2 R$ per month will be sufficient to cover the monthly billing and collection costs per user.

Technical Sustainability

The field study confirmed that the installations were mainly made in accordance with the standards defined by CEMIG. Except for minor variations, they were equivalent to the model installation set up for demonstration and training at the EFAP in Sete Lagoas. It may be supposed that CEMIG's specialized training of responsible technicians and efforts aimed at broad quality control contributed to the good quality of the PVS installations.

The user interviews in the community of Algodoeiro (district of Diamantina) showed that CEMIG decided on system size without any client participation. In most cases system size (single or double system) appeared to be adapted to house size but not to the real demand of the consumers. This led to overdimensioning of systems in several cases. Some users of a double-sized system (100 Wp) had not even connected a radio to their systems. Hardly any televisions were observed.

Approximately 90 % of the technical problems in the Luz Solar program were due to ballast failures.[245] CEMIG is therefore planning to integrate an DC/AC inverter not only in the community systems but also in all future residential SHS. Replacement of the ballasts in each lamp by one central inverter DC/AC is expected not only to improve technical performance but also to reduce O&M costs significantly, compensating for the additional investment cost. One side effect of this measure is improvement of the supply situation for domestic appliances, since appliances operating on AC are more available in the local market. In case of pre-electrification this has the additional advantage that consumers will not have to replace appliances when they are connected to the grid.

Our look at the CEMIG delivery model revealed the following key points concerning maintenance:

The qualifications of the CEMIG staff, quality control efforts, and the will of the company to provide an all-embracing maintenance service have a positive effect on technical sustainability. However, the present situation, with CEMIG being responsible for all types of maintenance (including replacement of lamps), does not appear desirable, since in effect it means that users remain completely dependent on CEMIG staff, and local capacities are not fostered.

The definition of an entry point in the future will clarify the division of maintenance responsibilities between agents. In particular maintenance and replacement of the battery, which is a key factor for the sustainability of every PVS project, is to be taken care of by CEMIG.

However, there is one problem that has to be solved, especially for the SHS that work with DC (12 V): if the users are responsible for maintenance after the entry point, components like lamps, ballast, etc. and DC appliances have to be available in the local market.

To inform the technician in cases of failure before the entry point, CEMIG will have to provide formal and reliable channels of communication. One especially problematic factor appeared to be a lack of information about how to inform the CEMIG technician in cases of failure. The field study showed that users in general showed a very passive attitude and simply waited for the technician to pass by and solve their problems. This led in some cases to several weeks of supply interruption. The use of a free phone number to contact the service center could be a first step, but, as telephones are rarely available in the project regions, other communication channels have to be established as well.

245 Information gained during an interview with representatives of CEMIG (March 31, 2003).

For cost considerations, CEMIG has recently rationalized its maintenance net, reducing technical staff and concentrating its regional maintenance centers. Given the present maintenance structure, it appears unrealistic to expect CEMIG to be able to provide prompt service for distant PVS projects, i.e. service comparable to that typical for the grid. Obviously this will depend on the exact definition of “prompt.” Thus far ANEEL has not defined any quality standards for PVS supply (e.g. maximum supply interruption frequencies and durations).[246]

True, CEMIG undertakes considerable efforts to instruct users about the handling of their systems (specific information material, making use of the school PVS to encourage learning processes, etc. – see above). However, the field study in Algodoeiro showed that there was room for improvement concerning user instruction. Most users had little knowledge about the handling of their SHS. Regular repetition of the handling instructions would appear to be desirable.

Other Factors

Since CEMIG is responsible for grid electrification, close coordination with the grid extension is given. This fact becomes manifest e.g. in the concept of pre-electrification that has already been successfully implemented: several former SHS users have been connected to the grid, and their systems have been transferred to more distant houses. The pre-electrification concept allows for an acceleration of the rural electrification process.

In spite of the selection criteria defined for communities, there seemed to be no fixed criteria for the selection of the houses that will be benefit first when demand is higher than the number of installed PVS. In the community of Algodoeiro, a local association leader collected the signatures of 150 families interested in a SHS, but the municipality was only able to pay for the investment costs of 90 SHS.[247] The fact that during our visit people from the community came and asked for installation of a SHS showed that demand was not satisfied.

11.5 Summary and Conclusions

During the field study four SHS projects with four different delivery models were visited (Table 6 describes the characteristics of the respective delivery models in more detail):

- a (cash and) credit sales model (implementing agent: APAEB),
- a leasing model without ultimate purchase (implementing agent: FTV),
- a community-based service model (implementing agent: CAR),
- a utility-based service model (implementing agent: CEMIG).

These SHS projects were assessed as regards their technical and financial sustainability (see Table 7). Before discussing in more detail the conclusions on the achievement of technical and financial sustainability (Sections 11.5.1 and 11.5.2), the study highlights the following central observations:

One of the main distinguishing elements of the four approaches is the regulatory framework. CEMIG is bound by the regulations governing the electricity sector, including outreach targets, tariffs, and quality of service (see Chapter 9). This implies that demands on project performance as regards technical and financial sustainability have to be brought into line with regulatory demands. This is not true for the other three approaches.

246 See Ch. 9.3.

247 Information gained from a CEMIG official and the mayor of Diamantina, April 2- 4, 2003

Table 6: Description of the SHS Projects Visited				
Implementing agent	**APAEB** (Rural cooperative)	**FTV** (Nongovernmental organization)	**CAR** (Rural development company)	**CEMIG** (Utility/ distribution concession holder)
Delivery model	(Cash &) credit-sales model	Leasing (without ultimate purchase)	Community-based service model	Utility-based service model/ regulated-market framework
Property of SHS	User	Micro-entrepreneur	Rural association	CEMIG
Financing of investment costs via	Revolving fund	Donations and subsidized credit	Grants	Partially grants & subsidized credits
Responsibility for repayment of investment capital	User	Micro-entrepreneur	Government of Bahia	CEMIG, municipalities
Maintenance service provider	Independent technician on a commercial basis	Not clearly defined (during first period FTV)	Specially trained association members/ users	CEMIG technicians
Responsibility for payment of O&M costs	User, guarantee fund	Not clearly defined (during first period mainly FTV)	User, maintenance fund	Today: CEMIG (future: partial responsibility of user)
Regular monthly user payment (investment and/or O&M)	~R$ 18 (for a 64 Wp system); price in R$ depends on the price of goat meat (index)	R$ 12-14	R$ 9.50 (recommended); R$ 0-5 (empirical)	Today: R$ 0 (future: ~R$ 2 = regulated tariff for low-income rural households)
Marketing and initial user contact	APAEB	FTV	CAR (through municipalities and rural associations)	CEMIG and municipalities
Selection criteria for project area/ communities	Open only to members of APAEB and collaborating associations	Ability to pay, distance to grid, existence of potential micro-entrepreneurs	Organizational capacity, distance to grid, use of traditional energy, political considerations	Distance to grid, dispersion, adequate O&M conditions, political considerations
Selection of users	Market mechanism	Market mechanism	Management of rural association	Municipality/ local association
Size of solar panel	64 - 128 Wp	42 - 64 Wp	50 Wp	50 - 100 Wp
Source: Own compilation				

Generally speaking, target regions for SHS projects are often characterized by weak local capacities (technical, managerial), poor development of local markets (especially for components and appliances suitable for SHS), a low degree of target-group political organization, and difficult access. Nevertheless, these conditions for the implementation of SHS projects vary across project regions. The APAEB project and the CAR project in Nazaré (district of Arací) are examples for how more favorable conditions may have positive effects on project performance. However, these should be considered not as typical cases but more as exceptions.

Obviously there is a certain trade-off between maximizing outreach (as intended by the Brazilian universalization initiative) and reaching technical and financial sustainability. While the CAR and the CEMIG approaches focus more on outreach, the philosophy of the open-market approaches of APAEB and FTV is centered more on (financial) sustainability (with implementation relatively successful in the case of APAEB and unsuccessful

Table 7: Assessment of the SHS Projects Visited

Implementing agent	APAEB (Rural cooperative)	FTV (Nongovernmental organization)	CAR (Rural development company)	CEMIG (Utility/ distribution concession holder)
Technical sustainability: Strengths (+) and weaknesses (–)	Regular/ Bad: Flexible dimensioning (+); local market for spare parts and DC appliances (+); quality of installation and components (–); quality of maintenance (–)	Bad: Local market for spare parts and DC appliances (+); quality of components (–); dimensioning (–); availability and quality of maintenance (–)	Regular/ Bad: Quality of installation (+); quality of maintenance (–); availability of spare parts and DC appliances (–)	Regular/ Good: Quality of installation (+); quality of maintenance (+); availability of maintenance (–); availability of spare parts and DC appliances (–)
Financial sustainability: Strengths (+) and weaknesses (–)	Regular/ Good: Fee collection (+); ability to pay (+); flexible and indexed payment mechanism (+); long term sustainability at risk because of shrinking revolving fund (–)	Bad: Ability to pay (+) Fee collection (–); *Comment: Bad financial sustainability is a consequence of bad technical sustainability and badly defined maintenance responsibilities*	Regular/ Bad: User contributions too low (–); fee collection (–); *Comment: Performance depends on local conditions (management capacity of rural association, solidarity, authority)*	At present: Bad: No fees collected (–); *Comment: In the future financial sustainability can be achieved at scale of overall concession area if PVS projects are included in the sectoral cross-subsidy scheme*
Coordination with grid extension	Bad *Comment: User bears risk auf misallocation*	Bad *Comment: Micro-entrepreneur bears risk of misallocation*	Bad *Comment: Gov. of Bahia bears risk of misallocation*	Good *Comment: CEMIG bears risk of misallocation*

Source: Own compilation

in the case of FTV). A common characteristic of the APAEB and the FTV models is that actuation areas and users are selected according to their ability (and willingness) to pay. They are therefore not wholly compatible with the goal of universal service coverage.

As regards the levels of monthly user payments, the APAEB model shows that R$ 18 is affordable and feasible. However, under a perspective looking at universal coverage this should not be considered a replicable model (see above). On the other extreme there seems to be room to increase the regulated maximum tariff for low-income households (R$ 2 per month in the case of Minas Gerais) which CEMIG intends to charge to SHS users, without overstraining their ability to pay. This measure would improve the financial sustainability of the CEMIG model. Increases in regulated tariffs have to be authorized by the regulatory agency ANEEL. Roughly speaking, monthly payments of about R$ 10 for an integral solar electricity service appear to be affordable for the majority of the target population.[248]

The four projects have opted for different maintenance models. While the APAEB, the CAR and the FTV approaches rely more on local maintenance capacities (decentralized model), the CEMIG approach relies on a centralized model with qualified technicians located at regional maintenance centers. In areas with favorable conditions (education, development of local markets) relying

[248] This is especially true when flexible payment mechanisms are used (see below). R$ 10 is equivalent to about 4% of the actual Brazilian monthly minimum wage (R$ 240).

primarily on local maintenance capacities seems to be a reasonable choice. However, experiences from the programs of CAR and FTV show that building reliable local maintenance services in areas with less favorable conditions may prove to be very difficult. In these areas some centralization of maintenance services seems to be preferable. However, what is needed in any case is an optimal articulation of the maintenance chain with basic maintenance tasks (mainly related to preventive and routine maintenance) provided locally and more complex maintenance tasks provided by trained technicians located at regional centers. It is essential to establish reliable communication between the links of the maintenance chain.

Whenever resources from public budgets (federal, state or municipal) are used to subsidize the investment costs of electrification projects, and whenever there is room for discretion in the allocation of these resources, political considerations will play a role in deciding on project location. This increases the risk that project allocation will follow a clientelistic rationale.

11.5.1 Technical Sustainability

Success factors for technical sustainability relate to the quality of dimensioning and system design, the quality of installation, and the quality and the availability of maintenance services. Table 8 contains the main findings (key factors and instruments). In what follows the points contained in the table are illustrated.

Flexible installation norms for SHS and adaptation to user needs and preferences will raise user satisfaction and prevent home-made alterations, which often lead to technical problems.

Availability of **components** can be improved through development of a local market for spare parts, as can be seen in the APAEB project.[249] Component quality can be improved through national quality standards and control mechanisms. In the case of Brazil, these would be of special importance for the electronic ballast, the frequent failure of which in all projects visited gave rise to high maintenance costs. This is a task that calls for action on the part of national quality management institutions like the Instituto Brasileiro de Normas Técnicas (INMETRO).

Key factors for the **availability of maintenance** are local organization and communication. If users assume basic maintenance tasks and trained local personnel is responsible for supporting the users and carrying out slightly more complex maintenance activities, simple problems can be solved quickly and users do not have to wait for a remotely based technician to come (however, quality of maintenance suffers if it relies too much on trained locals). In the projects visited, distance was the main reason for variations in waiting times between one day and several weeks – except for the FTV project, where failure times of several months were due to unclear responsibilities. Another reason for long waiting periods was the lack of communication structures. Clearly defined and formalized communication channels, such as a free-call telephone number or a designated local person are essential to inform the technician about failures.

The **quality of maintenance** is essentially determined by the **capacity-building** of the agents involved. Standardized training of technicians, such as that provided by CEMIG in the training center in Sete Lagoas, makes for qualified personnel, but it becomes costly if the trained personnel does not stay on the job for long.[250] Frequent change of local personnel in general lowers the quality of service. A strong local organization and a sense of project ownership can prevent such frequent change. However, the underlying structural "brain-drain-problem" of rural areas is a

249 For these markets to be profitable, a critical number of systems has to be reached.

250 Reasons for frequent change may be migration to cities, where trained technicians can get better jobs, or organizational, when the new mayor does not renew the contracts for technicians that are trained by the service provider and paid by the municipality (this was the case in a earlier delivery model adopted by CEMIG).

Table 8: Key Factors and Instruments for Technical Sustainability

Key factors	Instruments
System Dimensioning and Design	
▪ Adaptation of capacity and installations to the demands and needs of clients (sockets, DC vs. AC, etc.).	▪ Development of adequate indicators for estimation of demand (load) ▪ Flexible norms and possibility to enlarge the systems
Installation	
▪ Quality of components and installation services ▪ Supplier guarantee (coverage, duration, realization)	▪ Set and control standards for components (especially "sensible" components such as ballast and battery) and certification of installation firms ▪ Use of market power (negotiating) ▪ Monitor supplier guarantee ▪ Minimize storage time for batteries
Operation and Maintenance	
▪ Quality and availability of spare parts ▪ Quality and availability of maintenance services ▪ Organizational capacity of local community ▪ Communication of technical problems ▪ Transparent division of responsibilities ▪ Organizational stability	▪ Stimulation of local market for components or inclusion of DC/AC inverters in the system ▪ Quality control of spare parts (especially ballast) ▪ Capacity-building for all agents (standardized training of technicians, repeated user information) ▪ Monitoring to encourage learning process about procedures and responsibilities ▪ Formalization of complaint/ information channels (telephone, personal). ▪ Formalized division of responsibilities (contracts, blueprints etc.).

Source: Own Compilation

hindrance to the provision of the integral maintenance service by well-trained local persons.

Across the four projects, a trade-off can be discerned between quality and availability of maintenance service: locally organized maintenance is readily available but often of low quality. Centralized maintenance, on the other hand, is of good quality but less available and more expensive.

Thorough and repeated **user training** makes for adequate operation of the SHS. This training has to include information about handling the system, battery functions, and the system's limited capacity. It should be regularly repeated, e.g. during the technician's visits once a month, as was intended in the FTV concept.

If maintenance is actually to take place and capacity-building to be successful, one prerequisite is a clear and formalized **division of responsibilities**. As can be seen from the FTV project, an unclear division of responsibilities can lead to disastrous results.

11.5.2 Financial Sustainability

The main determinants of financial sustainability at the project level are, on the one hand, the amount of investment, capital, and O&M costs to be covered (this determines the cash flow that has to be generated) and, on the other hand, ability to pay and willingness to pay of the users as well as enforceability of payments (these factors determine whether the necessary cash flow can be collected). The standard set was that the minimum requirement for financial sustainability was to be coverage of O&M costs through user contributions as a means of guaranteeing project self-sufficiency.

Costs

The amount of overall costs to be covered depends on an entire array of factors, two of which will be addressed here:[251]

One determinant of investment and O&M costs is the quality level of the PVS service to be achieved (see requirements for technical sustainability; it is anticipated that ANEEL will issue a regulation concerning the quality of PVS services by the end of 2003[252]). High-quality service usually requires relatively high costs for the development of a system design adapted to local conditions, good quality equipment, qualified technicians, building of a maintenance network, capacity-building of locals, good quality spare parts, etc. Investment in good quality and capacity-building hopefully will result in longer component lifespans, lower failure rates, and consequently even lower lifespan costs than in the case of a low-quality approach. However, this does not change the fact that these costs must first be covered before they can result in a (uncertain) pay-off. There is, therefore, a trade-off between minimizing costs and achieving a high level of technical sustainability. This is especially true in a short-term perspective.

251 See Santos (2002) Ch. 6 for a thorough cost analysis of electricity supply via PVS in Brazil. See also Ribeiro (2002), Ch. 6.

252 This regulation will definitely apply for the Brazilian concessionaires. It is not clear if such a regulation would apply for other providers of electricity services via PVS.

A second important determinant for the amount of investment and O&M costs that have to covered are the locational characteristics of the project area. Long distances from the next urban center, difficult access, low user educational levels, and poor development of local markets will result in relatively high costs. These locational characteristics often correlate with a high share of poor households. Consequently, there is a trade-off between minimizing costs and achieving a high outreach (in spatial terms as well as in terms of reaching the poorest households).

Ability to pay

The ability to pay of a given area is mainly determined by the characteristics of the local economy (see above). There may be big differences concerning the ability to pay of potential consumers between different regions as well as within the same region.[253] Ability to pay cannot directly be influenced by project management. However, there is the expectation that the provision of electricity services through PVS can indirectly stimulate income generation in the benefited regions.[254] The empirical evidence on this issue for the cases of residential SHS and school and community center systems is addressed in Chapter 12, below.

The actual ability to pay of consumers is a important determinant for achieving financial sustainability. There are different strategies to deal with low ability to pay. These strategies could be used complementarily:

The first strategy is to select regions and users with a sufficiently high ability to pay. This was successfully done in the FTV and APAEB projects. This approach is typically pursued in more market-oriented projects (often sales models) in a open-market-framework. There is a trade-off between this strategy and the aim of reaching the poorest households (outreach goal).

253 See also pyramid model in Ch. 5.

254 Indirect (income-generating) effect of the provision of rural energy services. See Ch. 8.

A second strategy is to adapt payment modalities to the income situation of the consumers, e.g. to the sources of and variations in rural incomes. The approach followed by APAEB was to index payments to an important source of income and to allow for longer payment periods, e.g. annual instead of monthly period. Another way is to smooth the (maintenance) costs over time, e.g. by establishing a maintenance fund that is fed by regular but small user contributions (see e.g. CAR model). It is possible in this way to prevent expenditures for a new battery etc. from overstraining the consumers' ability to pay at a given point in time.

A third strategy is to use subsidies to substitute for a lack of ability to pay. This approach was pursued by all projects, especially by CAR and CEMIG.

It was argued that, for sustainability reasons, instead of being subsidized, O&M costs should be borne by the users. However, depending on the quality of service to be achieved as well as on locational characteristics, the O&M costs may be considerable (estimates indicate an amount of R$ 17 to 21 per month).[255] This would mean that many potential consumers in the target regions for PVS electrification in Northeast Brazil would have to be excluded, since their ability to pay is too low to achieve financial sustainability. Without sacrificing financial sustainability, it is possible to achieve higher subsidy levels by integrating PVS activities into the regulated-market framework and making cross-subsidies available (see the discussion in 11.4.2 of an alternative criterion for financial sustainability: *equilibrio econômico-financeiro*). This seems justifiable in cases like Brazil, where the target of universal coverage is a political priority.

Willingness to pay

The willingness of consumers to pay for SHS depends on the perceived benefit of the systems, transparency of information about the technical characteristics of PV electricity and the related costs, and the availability and costs of grid electricity.

The perceived benefit of the SHS has very much to do with the technical performance of the system. High failure rates, short battery lifespans and a lack of maintenance services will significantly reduce willingness to pay (see FTV project). It is therefore essential to guarantee the technical sustainability of the systems.

Willingness to pay is reduced by intransparent or misleading information about the technical features of the SHS (e.g. capacity, i.e. type of appliances that can be used and duration of daily electricity consumption), the handling requirements, and the related costs (depending on delivery model, clear information must be given about credit costs, maintenance costs, costs of spare parts). Emphasis must be placed on informing users about the end of the producer guarantee and the consequences for maintenance costs.

Willingness to pay for SHS is also influenced by the quality and the costs of alternative energy services. There is no doubt that PV electricity is greatly preferred to traditional illumination with diesel or kerosene (see Chapter 12). However, many users prefer grid electricity to PV electricity, especially if the costs are similar or even lower thanks to subsidized grid electricity tariffs. Therefore, if grid electricity is available or the connection to the grid is promised by local politicians at low costs for consumers, this will reduce willingness to pay for SHS.

The relatively good performance of the APAEB model concerning fee collection supports the hypothesis that property of the SHS enhances willingness to pay.

Enforceability of payments

Factors that foster the enforceability of payments include a high willingness and a sufficient ability to pay (see above), a clear and formalized specifi-

255 See Ch. 11.4.2.

cation of responsibilities and payments, the legitimacy of the fee collector or institution, as well as the continuity of local project management.

It is essential that ownership issues and the responsibilities for bearing credit, leasing, and maintenance costs are clearly specified and formalized (see FTV model for a bad example). The division of responsibilities will vary according to the delivery model chosen. A (standardized) contract prevents misunderstandings. Also, collection of payments should be formalized by issuing receipts or bills.

Another factor influencing the enforceability of payments is the perceived legitimacy of the project management. Cost transparency and measures promoting the credibility of the organization as well as community involvement in order to establish a sense of ownership help to enhance this legitimacy, as is the case with APAEB. Interestingly, the authority of the staff is a success factor as well. Local persons may lack the authority needed for fee collection and thus depend on the support of "authority persons" from strong institutions (see experiences of the FTV project).

Another point related to legitimacy and authority is the availability of sanction mechanisms for cases of non-payment. Usually, enforcement of sanctions requires high legitimacy and/or authority on the part of local project management, since recourse to the closest judicial institution involves high costs and thus often is not a practicable alternative for settlement of disputes. If the local project management lacks legitimacy and authority, sanctions cannot be enforced. Moreover, sanctions are often not applied for reasons of solidarity.

One matter related to the previous point is the fact that in decentralized, community-based approaches (see CAR model) the stability and legitimacy of the local project management often depend on one single person (typically the leader of the local association or another person with leadership functions). If this person leaves the project area, this may endanger not only the enforceability of payments but the whole of the local project management. The continuity of local project management capacity could be fostered by building a broader base through community involvement and capacity-building.

12 Rural Development Impacts of Photovoltaic Systems

The following section presents the empirical results concerning the problem dimension "development impacts." This chapter builds on the concepts developed in Chapter 8.

Various studies on the local impacts of electricity indicate that there is a positive correlation between electricity consumption and HDI.[256] In contrast to those studies, which usually use highly aggregated quantitative data, the present study aims at assessing in a qualitative manner the extent to which and the areas in which PVS are able to strengthen rural development. The following results are based on the investigation of SHS and PVS for schools and community centers (see Table 9 for a characterization of the PVS visited). PVS explicitly designed for a productive application (like electric fencing and irrigation) were not considered.

The data collected during the interviews indicate that the PVS in the projects visited:

- influence positively the quality of life of the rural population, and especially that of women and children;
- can stimulate the quantity and the quality of education, if electricity supply is coordinated well with local authorities and national educational programs;

256 See Reddy (2002) and Ch. 8 of the present study.

Table 9: Characteristics of the PVS Visited

	1) SHS (88 cases)	2) Community/School PVS (8 cases)
PVS size	40Wp – 100Wp	150Wp – 2000Wp
Inverter DC/AC	No	Yes
Use	Illumination (*always*) Radio (*almost always*) TV black/white (*common*) Blender (*less common*) Cellular Phone (*less common*)	Illumination Parabolic antenna Color TV VCR Computer (*less common*) Refrigerator (*less common*)

Source: Own compilation

- typically do not directly stimulate income-generating activities among the rural population.[257]

12.1 Quality of Life

SHS users usually highly appreciate their SHS, mainly because they serve to increase quality of life. This assessment was confirmed in almost all user interviews and also in various expert interviews.[258] Quality of life refers here to health and security issues but also to entertainment and gender aspects.

Easy access to illumination at any hour substantially relieves daily burdens and enhances any type of domestic activity, like cooking and eating,[259] cleaning, caring for children or older people, social activities, etc. Since electric lighting substitutes for the indoor burning of kerosene or diesel for illumination, SHS improve the sanitary and health situation of household members considerably (reduction of burns, damages to eyes, and respiratory illnesses). Moreover, electric illumination creates a sense of security among users, since it enables them to identify dangers more quickly (for example poisonous animals).

The possible health and environmental dangers resulting from discharged batteries seem to be low because in all projects empty batteries were bought by traders in the cities. This set reasonable incentives for users to return their batteries.[260] Nevertheless, the discharged batteries can cause considerable health risks, especially for children.

The vast majority of users appreciated radio and TV, on the one hand because of the possibility to obtain information and on the other hand for entertainment opportunities.[261] Access to information is an important element of social inclusion among the rural population, most of whom are de facto excluded from social participation due to their geographical and socioeconomic conditions. This can open up new channels for political participation of the persons benefiting.

257 Campen/ Guidi/ Best (2000), Ch. 3, come to similar conclusions using a different methodological approach (scope: worldwide; methodology: desk study, surveys/ interviews with PVS project managers/ key persons, review of literature and project documents).

258 Information gained during interviews with representatives of Instituto Eco Engenho (March 12, 2003) and Instituto Pro Citta (March 26, 2003).

259 One interviewed person stated: „Now I can see, what I eat." ("Agora eu vejo o que eu como.").

260 The users generally receive between R$1 and R$3 per discharged battery.

261 Most of the persons interviewed already had a dry-cell-run radio, and some even had a TV run by an automotive battery *before* they received the SHS (this information was confirmed during interviews with Instituto Eco Engenho on March 12, 2003, Instituto Pro Citta on March 26, 2003, and representatives of UNIFACS on February 20, 2003).

Typically women and children benefit most from SHS, as they spend relatively more time at home. Therefore, women usually have had to inhale more kerosene or diesel smoke prior to installation of the SHS. Moreover, SHS eases their daily burden by permitting them to work during the evening hours.

12.2 Education

Residential and community PVS can improve the educational situation in rural areas for children and for adults. However, frequently these opportunities are wasted for lack of political coordination between electrification and educational policies.

Residential PVS: Illumination enables children and adults to study during the evening hours with a constant and high-quality source of light. Still, studying is not a common activity in the evening hours. Usually the electricity is used for entertainment and relaxation in the evening hours. Generally, children make more use of the improved education opportunities than adults do.[262]

PVS for schools and community centers are a means of raising the quantity and quality of teaching in rural schools. Evening classes can be offered for adult literacy or other relevant subjects like the use of computers. This enlarges the scope of teaching. Quality can be positively influenced by the use of video tapes, TV, and computers in classes for children and adults. Various teachers in rural schools stated that especially night classes for adults are better attended because of the constant light supply.[263] Apart from that, refrigerators improve the quality of the food given to children in schools and offer the possibility to cool vaccines. Nevertheless, the majority of the schools had no refrigerators.

Still, the new opportunities are often wasted due to political coordination problems. This is especially important in the case of the PRODEEM program (see also Box 7). One important program activity is to install PVS in schools. Usually the municipalities are responsible for maintenance and either the municipalities or the ministry of education provides TVs, VCRs, and other appliances. This worked well in only 2 of the 5 schools visited.[264] The reasons were that municipalities had not been informed of their tasks, the ministry of education had not provided appliances, or nobody took care of maintenance. The adequate use of PVS for education depends to a large extent on the availability of material and human resources in the municipality as well as on the coordination between different administration levels and ministries. Frequently the municipalities neither have the money to buy the necessary appliances (for example a parabolic antenna or a VCR) nor can afford additional evening classes. This illustrates the importance of political coordination between energy and education policies as well as between different administration levels.

12.3 Income Generation

SHS have two possible impacts on the income situation of households. The first is the cost resulting from the purchase and/or maintenance of the system and the second is new income-generating activities made possible by electricity.

The monthly expenditures for SHS vary considerably among the different projects (see Chapter 11). Generally speaking, these costs are equal to

262 The illiteracy rate among the adults interviewed was relatively high. See also Ch. 10 for the illiteracy rates of the districts visited.

263 Before the installation of PVS, night classes were illuminated by gas lamps which provide a insufficient light intensity. One problem for evening classes, though, is the long distances between residences and schools: some users told us that they are too tired in the evening hours to walk an hour or more to get to class and that it is too dangerous to walk in the dark.

264 Strictly speaking, in Minas Gerais. Coordination varies considerably between different states. The bad performance (lack of appliances, lack of maintenance, lack of teachers for evening courses) of PRODEEM in Bahia is confirmed by Fontoura (2002), p. 63.

or lower than the monthly expenses for energy prior to installation of the SHS,[265] i.e. this effect is either neutral or positive.

Our interviews indicate that, apart from very few exceptions, the use of SHS did not contribute to increasing household income by stimulating income-generating activities (e.g. handicrafts at night). Long-term effects on income generation that may result from enhanced educational possibilities were not analyzed.

To promote new income-generating activities, two factors are especially important: i) an integrated rural development policy and ii) (usually) higher amounts of electricity than are provided by a typical SHS:

An integrated rural development strategy must contain different elements in various areas. It should aim at fostering local organizational capacity and entrepreneurship. In addition, it has to open up and stimulate access to markets for the products and services produced by the rural population. This means, on the one hand, that is essential to provide capacity-building in different areas, enhanced education and training opportunities. On the other hand, basic infrastructure services should be improved (electricity is one among others – like roads, water, schools, and health centers). And finally, political and social participation of the rural population also has to be raised.[266]

Relatively high amounts of energy are a necessary condition for new income-generating activities (for example, irrigation or the use of machines to process manioc or corn). PVS can meet these needs only in part, since the systems designed to providing high loads are very expensive and, consequently, not competitive. This means that provision of higher loads to encourage local employment and income generation often has to go along with other technologies than PV (see Chapter 4).

One interesting example of how PV technology can support rural economic development is the CEMIG/GTZ project "uso racional da energia na agricultura" (rational use of energy in agriculture, see Box 8).[267] This project shows how a combination of higher energy supply for production purposes provided through the grid and PVS for domestic use together with an integrated approach can improve rural living *and* income conditions.

12.4 Conclusions

The electricity provided by PVS is an important factor involved in improving the quality of life and self-esteem of the rural population. It contributes not only to reducing risks of daily life but also to relieving the daily work burden, making available time for other activities, improving education and information, and promoting social integration. The impact on the daily life of women and children should be noted here.

In terms of income generation, SHS and PVS for schools and community centers will most probably not directly create substantial new opportunities. Nevertheless, they can be a basis for enhanced economic development, by contributing to better illumination, education, and information, if other bottlenecks are overcome in the same way.

These benefits are unlikely to be realized if electricity supply is an isolated measure. It is highly important to embed electrification efforts in the wider context of an integrated strategy of rural

265 A typical monthly expenditure for candles, kerosene, gas, and diesel for illumination is about 12 to 14 R$ per month. Information gained during interviews with users and various experts (Instituto Eco Engenho, Instituto Pro Citta, BRASUS and UNIFACS).

266 A thorough analysis of approaches to stimulate agricultural and rural development in a decentralized manner is given by Brandt/ Otzen (2002), Part B. See especially Ch. 12 and the executive summary.

267 See Coelho (2002).

Box 8: The CEMIG/GTZ Project *Uso Racional de Energia na Agricultura*
The joint project *Uso Racional de Energia na Agricultura* (Rational Use of Energy in Agriculture) of CEMIG, GTZ, and the rural development agency EMATER-MG (Empresa de Assistência Técnica e Extensão Rural do Estado de Minas Gerais) is an example of an integrated rural development approach. The project aims at creating new rural income opportunities and contains elements of capacity-building, agroindustrial production and renewable energies for residential electrification. In 1994, the subproject *Casas de Máquinas* was initiated in the subregion of *Vale de Jequitinhonha*. Its purpose was to electro-mechanize agricultural production/processing and to create markets for agricultural products on a community basis. Examples include a local bakery (which uses new formulas to improve nutrition) and a processing unit for manioc, which were supplied with grid electricity. The integrated project philosophy aims at increasing the incomes of association members and small agricultural producers as well as improving living conditions and quality of life in sparsely populated areas. Another subproject is an SHS project. The SHS are a supplement to improve living conditions of households not connected to the grid. The SHS installed are passed on to other households when the grid is extended. CEMIG is responsible for the installation and maintenance of the SHS. The users pay a fee, which goes to finance battery changes: a 50 Wp PVS costs 4R$ per month, a 100 Wp SHS 8R$. Other spare parts are the user's responsibility.
Source: Coelho (2002)

development and to enhance the social organization of rural communities.[268] In such a context PVS are an important contribution not only to improving living conditions but also to reducing migration to the cities.

268 Experts stressed the importance of social organization and its apparent lack at the moment. Information gained during an interview with representatives from Instituto Pro Citta on April 5, 2003 and UNIFACS on February 20, 2003.

IV. Recommendations

13 Recommendations for German Development Cooperation[269]

13.1 Should Rural Electrification with Photovoltaic Systems Be Promoted by German Development Cooperation?

Two main arguments are usually stated in favor of the promotion of PVS projects by German development cooperation: first, their contribution to global climate protection, especially in the context of the new German Government's initiative on promoting renewable energies in developing countries. Second, their contribution to poverty reduction through stimulation of economic and social development in rural areas.

The contribution of PVS projects to climate protection must be assessed as relatively small, since off-grid PVS are a niche technology for applications with very limited loads. First, they avoid only small amounts of GHG emissions because they are suited for rural areas with low electricity demand. Second, the costs of emission avoidance are relatively high compared to other renewable energies, e.g. wind or small-scale hydro-energy. Third, the relation between the energy consumed in producing PV cells and the energy generated during the lifespan of a PVS is not very favorable compared to other RET. Thus, on a global level, off-grid PVS do not play a major role in substituting conventional energy sources. It still can be argued that they contribute to an ecologically neutral expansion of electricity supply. Nevertheless, the ecological justification cannot be the main argument for the promotion of off-grid PVS projects.

As regards the factor of contribution to poverty reduction, the empirical study has shown that SHS and PVS for schools and community centers successfully contribute to improving beneficiary quality of life and health conditions. As far as the economic dimension of poverty is concerned, the systems typically did not stimulate income-generating activities. This can be explained by two reasons. Because of their limited capacity SHS cannot be used to power larger-sized appliances and are thus restricted to basic electrification (illumination, the use of a radio and/or a TV). On the other hand, the target regions are in general structurally weak, and therefore electricity supply does not solve the problem of lacking income possibilities. In consequence, the economic impacts of PVS as a isolated measure must be estimated as very limited. Nevertheless, the use of PVS can play an important role as one element of a broader rural development strategy for poverty reduction.

Furthermore, it is generally not easy to organize the supply of a new and relatively expensive technology to a rural population with low purchasing power and low educational levels. The special barriers existing in structurally weak regions make it difficult to guarantee the long-term technical and financial sustainability of PVS projects. On the one hand, O&M costs are relatively high because the typical lack of local structures make additional efforts necessary to provide reliable maintenance service and organize fee collection. On the other hand, the low purchasing power of the population often rules out full cost recovery, indeed in many cases even recovery of the O&M costs. Thus, to guarantee technical sustainability most projects depend on provision of a substantial share of subsidies.

All these arguments plead for the position that promotion of PV technology for rural electrification should not be a priority field for German development cooperation. Nevertheless, in certain niches PVS can be an economically and ecologically rational measure to electrify the rural poor, considerably improving their basic living conditions. But to trigger broader development effects (income generation, political participation), PVS

269 Following the focus of the study, the recommendations refer mainly to projects concentrating on SHS and PVS for schools and community centers. Furthermore, the majority of statements are principally based on the results of the Brazilian case study, a fact which should be considered in generalizing the recommendations.

should be integrated, as one element, into a broader rural development strategy for poverty reduction.

13.2 If Rural Electrification with Photovoltaic Systems Is Promoted, What Should Be Done?

Once a decision to promote PVS projects has been taken, development cooperation should focus on the following three lines of action:

- to develop an adequate regulatory framework for rural electrification with PVS;
- to develop and implement sustainable delivery models for PVS adapted to the regional context;
- to integrate PVS projects in broader strategies for rural development in order to maximize development impacts.

13.2.1 Development of an Adequate Regulatory Framework

Measures taken at the regulatory level have to aim at the elimination of existing institutional, political, and economic barriers for rural electrification projects with PVS.[270] It is therefore especially important to create a level playing field for PV technology in the electricity sector.

Recommendations for the Brazilian Case

Under the special Brazilian circumstances, this means that policy dialogue should be used to support the Brazilian government in:

- Defining minimum standards for energy provision with PVS and other RET:

  Only when it is legally ensured that PVS are generally accepted as a means of universalization will Brazilian concessionaires be willing to invest in rural electrification projects with PVS and other RET;

- Defining tariffs for energy provision with PVS:

  To make possible a cost calculation for PVS projects, it is necessary to decide whether the legal PVS tariff will follow the customer classification valid for the central grid or whether there will be a special PVS tariff. If no distinction is drawn between grid and PVS energy supply, most PVS clients would be classified as *baixa renda*[271] and would pay the regulated maximum low-income tariff. This has implications for the financial situation of the service provider.

- Defining levels and procedures of and rules for the provision of resources originating from sectoral funds like CDE and RGR in order to finance universalization (with PVS).[272]

- Clarifying how best to integrate existing PVS projects and project management organizations (NGOs, rural associations, etc.) in the universalization process:

  One option would be to award permits to project management organizations that are running PVS projects and transform them into permissionaires.[273] Another possibility to integrate these project management organizations in the future universalization process would be to qualify them to act as delegated service providers (sub-contractors) of the concessionaires.

270 See Ch. 5 and 6.

271 See Ch. 9.3.

272 See Ch. 9.3.

273 See Ch. 9.3.

13.2.2 Sustainable Delivery Models for Photovoltaic Systems

There is no single best-practice delivery model because each model has to be adapted to the existing political, social, and economic conditions of the region as well as to the individual features of the executing organization. However, the following key points should be used as criteria for project evaluation.

Coordination of the project with the sectoral framework:

- Does the project fulfill the criteria set under national regulations (tariffs, quality standards, etc.)?
- Does the PVS project take into account the price signal of the central grid or does it charge substantial higher prices than the tariff charged to grid-connected customers?
- Is the project coordinated with grid expansion plans?

Use of PVS as a least-cost technology:

- Are there mechanisms to ensure that PVS are really the cheapest solution compared to other technologies?
- Does the PVS provider have plans to transfer the PVS to new users when the old ones have been connected to the grid?
- Does the business plan include a realistic calculation of the O&M costs?

Integration and promotion of local structures:

- Does the delivery model integrate existing local associations and authorities?
- Are local capacities involved in management and O&M procedures?
- Is capacity-building of users and training of local "technicians" an integral element of project conception?
- Does the model take into account communication and articulation with external (non-local) maintenance services, which require higher skills?
- Can the O&M costs be covered through local user payments?
- Is there a local market for suitable appliances and spare parts, or can such a market be developed in order to assure the availability of these items?

Formalization of the delivery model, quality control, and organizational learning:

- Is the division of responsibilities (especially maintenance and related costs) clearly defined and legally formalized on the basis of contracts?
- Is the quality of the components ensured by standardization?
- Is the quality of installations ensured by monitoring?
- Are there enough qualified technicians available for monitoring and corrective maintenance services?
- Are there monitoring procedures to provide information for organizational learning processes?

Recommended Delivery Model and Actions for Brazil

Under the special Brazilian circumstances, and in relation to the ongoing universalization process and the given regulatory framework, the **service model via concessionaires** appears to be the most adequate approach:

- A concessionaire as PVS service provider has the capacities to guarantee the long-term financing of a PVS project because of his privileged access to external or sectoral resources and the possibility he has to make use of cross-subsidies. The integration of the PV technology into the concessionaire's formal structure automatically leads to a coordination with the expansion of the grid and to adaptations of the PVS delivery model to national regulatory standards. Furthermore, a cost calculation based on market principles would guarantee that PVS are used as a least-cost technology either for definitive electrification or for pre-electrification. Such an approach could use existing organizations experienced with the local management of PVS projects as delegated service providers (sub-contractors) of the concession holder.

However, there are some **drawbacks** related to this approach that have to be considered and remedied by an adequate program design:

- Unless the uncertainties related to PV technology and arrangements for universalization (see above) are overcome, Brazilian concessionaires will not engage in a larger-scale in off-grid PVS projects.[274] Another factor that additionally hinders a broad application of PVS is a lack of experience with this new technology and resistance to it among managers of utilities and important political institutions (MME, Eletrobrás). Development cooperation should encourage the diffusion of experiences and best practices among utilities and political decision-makers.

- It is very unlikely that, given the present tariff regulations and the low ability to pay in the target areas, the concessionaires will be able to charge fees that cover the O&M costs. The most likely scenario is that the maximum low-income tariff (*baixa renda*) for grid customers will apply for PV technology. Thus financial sustainability (at the project level), defined as coverage of the O&M costs through user payments, will not be achieved. Still, this is not a "killer criterion," since ANEEL monitors overall concessionaire financial sustainability based on the concept of *equilibrio econômico-financeiro*.[275]

- The supply of electricity via PVS by a concessionaire entails the risk that project execution may face problems bound up with the need to give proper consideration to local structures and capacities. It is therefore important to integrate existing local organizations in the "communication and information system" as well as in maintenance (and possibly fee-collecting) procedures. In addition, these measures have to be accompanied by measures aimed at capacity-building for users and especially trained local "technicians." These capacity-building activities have to be adapted didactically to the low educational level of the target group. Development cooperation should support this kind of activities.

Another field of action relates to the **quality of components and technicians**:

- The poor average quality of some national components used in PVS, especially the electronic ballast, calls for action in the area of metrology and product standardization. Development cooperation should support Brazilian institutions in developing adequate standards. One important potential partner in this area is Instituto Brasileiro de Normas Técnicas (INMETRO).

- Under the assumption that PVS will have a widespread role to play in the universalization process, the availability of qualified technicians at the concessionaire level will constitute a bottleneck. Some utilities (like CEMIG or COELBA) have already acquired knowledge with specific training curricula. Devel-

274 CEMIG is rather an exception. Besides CEMIG, only COELBA carries out PVS electrification on a larger scale.

275 See Ch. 11.4.2.

opment cooperation could support the diffusion of training courses for PVS. Besides the concessionaires, one other important partner in this area is Serviço Nacional de Aprendizagem Industrial (SENAI).

13.2.3 Integration within an Adequate Strategy for Rural Development

Well-adapted and well-managed PVS projects are usually not sufficient to reach significant impacts on *economic* development. Experiences from many projects show that provision of electricity to structurally weak regions does not automatically lead to the desired catalytic effect. What is needed to stimulate regional economic development is coordinated and decentralized approaches which are open in terms of the technological energy solution to be used (options: SHS, community *and* productive use of PVS, small-scale hydro, biomass, grid extension etc.) and containing various fields of action (infrastructure, institutions, education and training, access to markets etc.). Thus efforts have to be made to develop and implement integrated rural development strategies of which PVS may be one element.[276]

Recommendations for the Brazilian Case

- Do not focus too narrowly on (residential) PVS, but consider various technological solutions adapted to local geographic, socioeconomic and market conditions.

- Improve the coherence of national rural electrification and rural development policies:

  Synergy effects and increased effectiveness could be achieved by means of better coordination between the following federal ministries: Ministry of Mines and Energy (MME), Ministry of Education (MEC), Ministries of Agriculture (MAPA), Ministry of Agricultural Development (MDA), Ministry of National Integration (MINA). Aside from this, policies have to be coordinated with state ministries and important institutions at the state level, like the Service for Technical Assistance and Rural Development (EMATER).

- Promote decentralization; integrate and strengthen local organizations and authorities.

- Focus on cooperation projects which combine elements of financial and technical assistance:

  In this way German financial cooperation could provide the resources necessary to finance the investment costs of a rural energy program, while German technical cooperation could accompany the planning and implementation of the program with technical assistance at the policy and project management level.

- Select strategic Brazilian cooperation partners:

  Cooperation with strategic partners like Eletrobrás, ANEEL, EMATER, and the concessionaires has the advantage that it is in this way possible to influence not only the management of PVS projects but also the policy level.

276 For examples in this direction, see the CEMIG/GTZ project *Uso racional de energia na agricultura* (Box 8) or the approach of APAEB (Ch. 11.1).

Annex

A1 Technical Design of a Solar Home System or Photovoltaic System for Schools and Community Centers

The Solar Generator

The **array** of a PVS usually consist of one or more solar panels which collect sunlight during the day and generate direct current (DC) electricity. The maximum capacity depends on the size of each panel and is measured in peak watt (Wp). A PVS adapted to the needs of a rural low-income household usually has a maximum capacity of about 20 to 150 Wp. In cases of higher energy demand, e.g. for clinics, schools, water pumps etc., it is possible to increase the array size. The solar array is usually mounted on a wooden or metal structure. It should be placed in such a way as to protect the panels from any harm or destruction. To ensure an optimal use of sunlight, the panels should be directed towards the equator and tilted at an angle.

To provide a 24-hour supply of electricity, the panels are connected to a battery bank which stores the electricity generated during the day. The **charge controller** manages the process of charging and discharging the battery bank. It is responsible for protecting the battery from overcharging or discharging too far; which reduces the lifespan and the capacity of the battery.

The Balance of System (BOS)

The **battery bank** typically consists of one or more rechargeable 12V lead-acid batteries with tubular plates and a storage capacity of 60 to 150 Ah. These “solar batteries” are the recommended type of battery for PVS because they are especially capable of delivering small amounts of power over longer periods and because they usually have a longer lifespan.

But since the special solar batteries are usually more expensive, sensitive to maltreatment, and not readily available in rural areas, users often employ ordinary automotive batteries with grid plates (SLI batteries – starting, lighting, ignition). Automotive batteries are relatively cheap (about US $ 60-80 per 100Ah/12V – about 3 to 4 times cheaper than a solar battery) but they have the disadvantage of a reduced lifespan of 1 to 3 years.[277] This lifespan usually depends to a high degree on working requirements and proper handling by the user. Thus the lifespan costs of automotive batteries are usually higher than those of solar batteries.

These costs can become a crucial factor for the economic viability of the overall PVS as well as for the willingness and ability to pay of low-income households. However, because of their advantages automotive batteries are at present accepted as the second best option for PVS in many developing countries.

Under ecological aspects, disposal of batteries is a major problem in that they contain hazardous materials. Thus the shorter the lifespan of the battery, the higher the environmental costs. Consequently, the lifespan of the batteries as well as the way in which their disposal or recycling is organized determines whether energy production with PVS still can be seen as ecologically less costly than other alternatives. The battery is therefore the most critical component of a PVS in terms of its technical reliability, its economic viability, and its ecological soundness.

The solar array and the battery provide direct current (DC) electricity (typically 12 V). Since some domestic appliances only function with alternating current (AC) an **inverter** can be installed to transform the low DC voltage to 110 or 220 V AC.

Domestic installations are part of the BOS. They include all components that are used to interconnect the solar generator and domestic appliances. For this purpose, it is important to use wires and

277 See GTZ (2001), pp.11-12.

cables of appropriate size; this minimizes resistance and a potential drop in voltage. Other necessary components are connectors, sockets, power outlets, switches, clips, channeling and tubing, as well as mounting hardware and terminals.

Aside from domestic installations, the BOS consists furthermore of **domestic appliances**, in the case of a rural household typically various fluorescent lamps, a radio, a TV, or in cases of other uses a water pump, a refrigerator, etc. Especially for SHS, the fluorescent lamps (and the electronic ballast) are another important factor influencing operating costs because these elements have to be replaced from time to time. Their lifespan usually depends to a high degree on product quality. When the system is run with DC, the fluorescent lamps are in need of an electronic ballast. The product quality of the electronic ballast may be a problem in some developing countries.

The **PV equipment costs** vary in accordance with national and local market conditions and component quality. Furthermore, there are innumerable types and sizes of solar generators, and even more overall SHS packages (see Table A1 below). The general rule, however, is that the smaller the PVS, the higher the cost per Wp installed.

Table A 1: Typical Categories of SHS

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
15 Wp investment cost: 543 US $	25 Wp investment cost: 706 US $	70 Wp investment cost: 1,068 US $	140 Wp investment cost: 1,677 US $	280 Wp investment cost: 2,069 US $
Appliance: hours/day	Appliance: hours/day	Appliance: hours/day	Appliance: hours/day	Appliance: hours/day
1 Lamp: 4 Radio: 5	2 Lamps: 6 Radio: 5	3 Lamps: 7 Radio: 4 TV or Tape: 3	5 Lamps: 11 Radio: 8 TV or Tape: 3.5 *One only:* Mixer: 0.25 Fan: 4 Sewing machine: 0.5	7 Lamps: 17 Radio: 8 Color TV: 3.5 Parabolic antenna: 3.5 *Two only:* Mixer: 0.25 Fan: 4 Sewing machine: 0.5

Source: ESMAP (2000), pp. 10-13

A2 List of Institutions Interviewed in Brazil

Institution

AF Engenharia, Salvador – BA

Agência Estadual de Regulação de Serviços Públicos de Energia, Transporte e Comunicação da Bahia (AGERBA), Salvador – BA

Agência Nacional de Energia Elétrica (ANEEL), Brasília – DF

Associação Brasileira de Distribuidores de Energia Elétrica (ABRADEE), Rio de Janeiro – RJ

Associação Brasileira de Empresas de Energias Renováveis (ABEER), Rio de Janeiro – RJ

Associação Comunitária de Saquinho, Fazenda Saquinho, Serrinha – BA

Associaçao dos Moradores de Nazaré, Povoado de Nazaré, Arací – BA

Associação dos Pequenos Produtores do Vale do Valente (APAEB), Valente – BA

Brasus – Brasil Sustentável, Brasília – DF

Companhia de Desenvolvimento e Ação Regional (CAR), Salvador – BA

Companhia de Desenvolvimento e Ação Regional (CAR), Escritório Regional Euclides da Cunha – BA

Companhia de Eletricidade do Estado da Bahia (COELBA), Salvador – BA

Companhia de Engenharia Rural da Bahia (CERB), Salvador – BA

Companhia Energética de Minas Gerais (CEMIG), Belo Horizonte – MG

Companhia Energética de Minas Gerais (CEMIG), Curvelo – MG

Companhia Energética de Minas Gerais (CEMIG), Sete Lagoas – MG

Cooperativa Valentense de Crédito Rural Ltda., Valente – BA

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Rio de Janeiro – RJ

Eletrobrás, Departamento Distribuição Urbana e Rural, Rio de Janeiro – RJ

Governo do Estado da Bahia, Secretaria de Infra-Estrutura, Salvador – BA

Governo do Estado da Bahia, Secretaria de Planejamento, Ciência e Tecnologia, Salvador – BA

Governo do Estado de Minas Gerais, Secretaria de Estado de Desenvolvimento Econômico, Belo Horizonte – MG

Instituto Eco-Engenho, Maceió – AL

Microempresa de Energia Solar, Sitio Conceição, Pão de Açúcar – AL

Microempresa de Energia Solar, Sitio Garrincha, Pão de Açúcar – AL

Mircoempresa de Energia Solar, Fazenda Sitio Palestina, São José da Tapera – AL

Ministério da Agricultura, Pecuária e Abastecimento (MAPA), Secretaria de Apoio Rural e Cooperativismo, Departamento de Infra-Estrutura e Extensão Rural, Brasília – DF

Ministério de Minas e Energia (MME), Secretaria de Energia, Departamento Nacional de Desenvolvimento Energético, Brasília – DF

Prefeitura de Diamantina, Diamantina – MG

Pró-Cittá, Instituto de Estudos pro Cidadania, Belo Horizonte – MG

Prorenda Bahia, GTZ/ Empresa Baiana de Desenvolvimento Agrícola (EBDA), Salvador – BA

Toscana Consultoria Internacional Ltda, Belo Horizonte – MG

Universidade Salvador (UNIFACS), Departamento de Psicologia, Salvador – BA

Universidade Salvador (UNIFACS), Mestrado em Regulação da Indústria de Energia, Salvador – BA

Winrock International Brazil, Salvador – BA

A3 User Questionnaire

DATA ____/_____/03	Entrevistador: Relator:	Acompanhantes:
ESTADO:	MUNICÍPIO:	PROJETO:
LOCALIDADE:	Distância da sede municipal ______Km	Distância da rede (estimativa) ______Km

1. Informação sobre a situação familiar do entrevistado(a)

1.1	Nome	Escolaridade	Idade	Sexo	Profissão
1					
2					
3					

1.2 Quantas pessoas estão morando aqui em casa?

1.3 Quantos filhos tem? ______ Quantos moram em casa?_______

1.4 Quanto tempo mora na localidade?

2. Informação socio-econômica:

2.1 Tem propriedade? Sim ( ) Não ( ), de quém é? Parente ( ) Alugado ( )

2.2 Qual tamanho ela é? ____ tarefas, hectares

2.3 Area construida? (Estimativa) 0-50 m^2 ( ), 50-70 m^2 ( ), mais que 70 m^2 ( )

2.4 Aparência geral da casa? Bem mantida ( ), normal ( ), descuidada ( )

2.5	O que plantam?	Sisal	Feijão	Milho	Mandioca		
2.6	Que animais tem?	Cabra	Galinha	Ovelha	Gado/Boi		

2.7	Fontes de renda	Renda agrícola (ao ano)	Trabalho assala- riado (mensal)	Governo (mensal)	Aposentadoria (mensal)
	Quantidade em R$				

3. Informação geral sobre o sf

3.1 Faz quanto tempo o/a senhor(a) tem o sf? ______ anos

3.2 Cómo está funcionando? Bem ( ), Mais ou menos ( ), Mal ( ).

3.3 O sistema é novo ( ) ou usado ( )?

4. Comercialização/ customização

4.1 Quem deu a informação ao senhor(a) sobre a oportunidade de ter um sf?

____

4.2 Teve a oportunidade de escolher entre vários tamanhos do sistema? Sim ( ) Não ( )

5. Instalação

5.1 Foi informado como usar o sf? Sim ( ) Não ( )

5.2 Como foi informado? Reunião especial ( ), Durante a instalação ( ), Papel na parede ( )

____

5.3 Sobre o que foi informado?

	Manutenção	( )
	Capacidade do sistema	( )
	Custo com manutenção	( )

____

5.4 Quem fez a instalação ?

____

6. Manutenção e Operação

6.1 Paga uma taxa mensal de manutenção? Sim ( ) Não ( ); Caso sim, quánto? _______

6.1.1 O/a senhor/a acha Caro ( ), Barato ( ), Normal ( ), Não sei ( )?

6.1.2 O/a senhor/a acha justo? Sim ( ) Não ( )

6.2 Os custos que paga agora são: Mais alto ( ) Igual ( ) Mais baixo ( ) do que informado antes ?

6.3 O/a senhor/a normalmente consegue pagar essa quantia?

Sim ( ), Geralmente sim ( ) Muitas vezes não ( )

6.3.1 Se não, é por que: Não tem dinheiro ( ) Não concorda com o pagamento ( )

6.4. Se o/a senhor/a continua sem pagar por mais tempo, o que vai acontecer?

Questionamento ( ) Bloqueio ( ) Desinstalação do sistema ( ) Não sei ( )

		bateria	lâmpadas	reator	
6.5	Quantas vezes teve que substituir uma peça?				
6.6	Quém fez? (U, F, PL)				
6.7	Pôde comprar as peças que precisava? Onde?				
6.8	Se não tem fundo de manutenção, quanto teve que pagar?				

6.9 Teve outros defeitos no sistema? ____

____

6.10 Se precisou de outra pessoa para consertar, cómo a informou? ______________________

____

6.11 Quanto tempo ela demorou para consertar? ______________________________

7. Financiamento do Custo de Investimento

7.1 O senhor comprou o sf ☐ Paga uma taxa de serviço ☐ Foi doado ☐ ?

7.1.1 Se o comprou, pagou de um vez só ☐ Quanto pagou? ________R$

recebeu um crédito ☐ Quanto paga ao mês?________R$

Quem lhe deu o credito ? O fornecedor ☐

Instituição de micro finanças ☐

Outros ______________________

7.2 Se paga uma taxa de serviço, quanto é ao mês? ____________R$

7.3 O/a senhor/a acha Caro ( ) Barato ( ) Normal ( ) Não sei ( )?

7.4 O/a senhor/a acha justo? Sim ( ) Não ( )

7.5 O/a senhor/a normalmente consegue pagar essa quantia?

Sim ( ) Geralmente sim ( ) Muitas vezes não ( )

7.6.1 Se não, é por que: não tem dinheiro ( ) Não concorda com o pagamento ( )

7.6 Se o/a senhor a continua sem pagar por mais tempo, o que vai acontecer?

Questionamento ( ) Bloqueio ( ) Desinstalação do sistema ( ) Não sei ( )

8. Uso

8.1 Que tipos de aparelhos usa?	**Quantidade**	**Quantas horas / dia?**	**Com sf**	**Sem sf**	**Já tinha antes**
1) Lâmpadas					
2) Candeeiro					
3) Lampião					
4) Ponto de Luz					
5) Rádio					
6) Televisão					
7) Liqüidificador					

8.2 Já usava bateria automotiva antes? Sim ( ) Não ( )

8.3 Gostaria de ligar mais aparelhos? Sim ( ) Não ( )

Quais?____

8.4 Teria como consegui-los? Sim ( ) Não ( )

9. Impactos

9.1 Que tipo de atividades a sua família desenvolve à noite? Ganha dinheiro com alguma dessa atividades (uso produtivo)?

Estudar ( )

Lazer ( )

Uso produtivo ( ) Qual:

9.3 Desde que tem o sf, tem mais ou menos visita a sua casa à noite?

Mais ( ) Igual ( ) Menos ( )

9.4 Quais outros hábitos da sua familia mudaram desde que tem o sf? (p.ex.: as crianças ficam acordadas até mais tarde)

9.5 O uso do candeeiro causou algum dano à sua familia? Sim ( ) Não ( )

Qual:

10. Participação na associação local

10.1 Como o senhor participa na associação?

Reuniões ( ) Freqüência:

Visita do Presidente ( )

Outros ( )

10.2 Como você avalia a atuação da associação?

Ótima ( ) Boa ( ) Ruim ( ) Péssima ( )

11. Para concluir a entrevista

11.1 Está contente com o sf? Sim ( ) Mais ou menos ( ) Não ( )

11.2 Conhece usuários perto daqui que tem outro sistema de eletricidade (diesel/ rede)? Acha que essas famílias tem um serviço de eletricidade melhor? Sim ( ) Não ( )

11.3 O/a senhor(a) preferiria estar conectado à rede elétrica? Sim ( ) Não ( )

12. Observações adicionais e gerais sobre a entrevista

12.1 Instalação

1 Dutos elétricos: Existem ( ) Não existem ( )

2 Estado geral da fiação: Bom ( ) Ruim ( ) Modificado ( )

3 Proteção da bateria: Existe ( ) Não existe ( )

4 Controlador de carga: Existe ( ) Não existe ( )

5 Proteção elétrica: Existe ( ) Não existe ( )

6 Tipo da bateria: Selada ( ) Não selada ( )

7 Capacidade da bateria em Ah: _________

8 Avaliação do procedimento para manutenção: Correto ( ) Errado ( )

____

12.2 Tipo de residência

12.3 Gerais

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