

# SMART MICROGRID SOLUTION: Integrated Distributed Control for Energy Access in India

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# About GeneralMicroGrids

- General MicroGrids, Inc is an international microgrids developer and systems integrator, working with governments, industrial customers and communities.
- As a Systems Integrator, GMI seeks to provide “end to end” solutions within the electricity value chain (from “source to sink”) for the power system integration and portfolio management of Renewable Energy and Demand-side Resources, using Smart Microgrid technologies.
- Safe, controllable and reliable Microgrids integrating renewable generation offer complementary infrastructure with customer assets to increase grid reliability, stabilize long-term energy costs and enhance environmental quality.
- Using information, communications and control technologies, “smart microgrids” can help communities achieve integrated energy solutions.

# **ENERGY ACCESS IN INDIA**

**Drivers for Rural Electrification**

**Smart Microgrids Can Provide New Solutions for Energy Access**

**Barriers and India's Rural Electrification Programs: Changing from Bottom Up & Top Down (Project and Market Development)**

**Leveraging Public Support for Private Investment: Building a "Policy Eco-System" for Smart Microgrid Market Development**

**"Bottom Up" Regulatory Support**

**Technology Standards, Resource Assessments, Pilots and Workforce Training: "Top Down and Bottom Up"**

**"Top Down" Market Development: Financial Interventions and innovations**

## **DRIVERS FOR RURAL ELECTRIFICATION**

**Largest unelectrified population in the world; Approximately 400 million People lack access to power in India; Vast areas underserved or face frequent blackouts and brownouts; Per Capita consumption of electricity is only about one-fourth of world average; Lack of Energy Access driving populace into crowded cities;**

**IEA estimates that to achieve universal access 70% of rural areas worldwide that lack access will need to be “connected” using alternative delivery networks (minigrids, microgrids) and new power sources that reach areas where it is not economically feasible to extend central grid services; Political pressures to deliver the requisite energy to satisfy increasing energy demand in India and to develop new resources to fuel productivity;**

**Advancements and Cost Reductions in Distributed Technologies are making these technologies cost-effective against Diesel Generators and changing the value proposition of clean Distributed Energy Resources (DER);**

**India’s “Smart Grid Vision and Roadmap” (Roadmap) reflects a shift from India’s traditional highly centralized, target-driven, supply-push electricity sector strategy to combining decentralized energy elements and reorienting to a customer/demand-driven approach using smart technologies; the Roadmap sets rigorous distributed resource, microgrid targets to provide universal access, manage peak demand, optimally use installed capacity and eliminate load shedding and blackouts;**

**Advanced in ICT and Telecommunications are affecting almost every facet of life.**

## **POTENTIAL FOR SMART MICROGRIDS**

**High costs of Central Grid extension into rural and remote areas necessitate alternative decentralized options such as smart microgrids and building the case for private investment;**

**Smart Microgrids could provide a cost-effective alternative to Central Grid Extension;**

**Microgrid systems less expensive than macrogrid due to lower infrastructure capital cost and lower cost of operations (avoiding transmission and distribution losses);**

**Designed and operated effectively could provide more reliable power, ensure local energy security, use locally available renewable energy sources; Renewable-energy based microgrids could displace diesel-based generation and reduce carbon footprint;**

**Smart Microgrids could be built upon household systems, off-grid lighting devices and minigrids, to provide electricity services on a greater scale and at less cost; going beyond residential applications, to provide power for commercial and agricultural applications, building productivity in the local economy; Smart microgrids could reduce the marginal costs associated with use of individual supply and renewable technologies;**

**Smart Microgrids could foster demand-side management and demand-side response; reduce power outages, increase reliability, efficiency and safety, and provide customers/communities control over their energy usage.**

# MICROGRIDS: INTEGRATED DISTRIBUTED CONTROL

## **“Smart” Microgrids Scalable and Sustainable – Moving from Facility Clusters to Villages to Networked Villages**

**Smart Microgrids** are **intelligent electricity distribution networks** that interconnect loads, distributed energy resources and storage within clearly defined electrical boundaries to act as a single controllable entity that can be grid-connected or isolated. Features include:

- Sensing, communication and control technologies used to generate, manage, distribute and use electricity more intelligently and effectively
- Electricity supplied by a diverse range of DER (diesel gensets, solar PV, micro- hydro plants, wind turbines, biomass, bio-gas, etc.)
- Distributed resources treated as an integrated and autonomous system
- Microgrid configuration localized to a customer, community or region
- Intelligent load and energy resource management; **balancing** loads with renewable's variable generation
- Integrate storage, load shifting, base plus variable generation with smarter grid
- Self-healing (detect, analyze, respond and restore itself in case of disruptions), self-configuring, plug and play

**India's Roadmap Microgrid Targets: 1,000 villages, industrial parks, commercial hubs by 2017; 10,000 by 2022; 20,000 by 2027 which can island from macrogrid during peak hours and grid disturbances.**

## **MICROGRIDS: INTEGRATED DISTRIBUTED CONTROL**

**Smart Microgrids, unlike “Minigrids,” can provide “Intelligent Distributed Energy Management,”** providing coordination and control to integrate multiple distributed energy, energy storage and demand-side assets within a common grid; and using specialized hardware and software systems to manage and optimize assets;

**Distinguishing Features:** Integration of multiple DERs, ensuring maximum use of renewable energy sources; Resource and load profiling, controlling and forecasting; Centralized control (Smart Hybrid Controller/Intelligent Dispatch Controller) for resource optimization and demand management; Load prioritization; Integrated communications infrastructure; Real-time data acquisition and monitoring of electrical and physical signals; Minimized outages and fast response to network disturbances through automatic connect/disconnect of system components (TERI RETREAT)

### **Potential Bankability (“Sustainability and Scalability”):**

- **Technical:** Reliable operation over expected lifetime, minimal downtime; modular ability to control, manage and optimize multiple supply and demand assets to balance supply and demand in real time;
- **Economic:** Energy and cost savings from asset portfolio optimization can generate revenue streams; Striking a balance between what customers willing to pay and ensuring project financial viability (adequate revenue to cover operational expenses, liabilities and profit; Networking and energy sharing could reduce operational costs/improve economies of scale; Configure to demand growth and to support community productivity; Systems architecture maximizes benefits and minimizes marginal costs of component technologies.

## SMART MICROGRIDS: SUSTAINABLE AND SCALABLE

- **Social:** Structured to promote public-private partnerships and build governance frameworks based on community buy-in and engagement; Development and operations aligned with frameworks that reflect the Human, Social and Cultural context (HSC); Development of locally available resources and design and operation of systems tailored to develop local enterprises and increase livelihood productivity; Networking of microgrid cells across village clusters enable energy sharing among communities with cost reductions;
- **Scalability:** “System of Systems,” building on lighting systems, solar home systems, minigrids and village load clusters, interacting with other microgrids within local energy networks and potentially serving as a macrogrid resource. “Distributed networked systems facilitate energy sharing and meet energy requirements cost-effectively through diversified portfolio of assets; Horizontal (Demand growth from population growth) and Vertical (Increased customer demand) scalability;
- **Environmental:** Maximize efficiencies and use of resources, lowering emissions and advancing resource integration (water, waste, transport buildings sustainability);
- **Equity:** Intelligent distributed energy management can yield more equitable and cost-effective results, providing universal, homogeneous service quality (reliability, power quality, resource availability and security, while also satisfying heterogeneous needs.

**Potentially Smart Microgrids as “Integrative Agents”: Fostering “Integrated Power Delivery” (Off-Grid and On-Grid) within an “Integrated Grid” (not a Super-Legacy Grid)**



## **BARRIERS and RISKS**

**Traditional Utility Business Model:** Cost ineffective to extend into rural areas; Does not recognize and fully take into account DER, microgrids, energy efficiency/capability of microgrids to cost-effectively harness benefits of DER/load management;

**Economic Challenges:** Low load (dispersed populations/low densities) and energy requirements, high cost to serve, high upfront capital costs, low capacity factors, inability of customers to pay, central grid extension uncertainty, higher tariffs;

**Technical Obstacles:** Microgrids traditionally customized/hard to replicate; construction and performance delays; technology failures; limited local technical capacity and weak supply chain linkages; Lack of institutional arrangements to assure reliable/efficient O&M; Increased costs of energy storage for using intermittent RE;

**Regulatory Impediments:** Lack of enabling policy, legal and institutional environment for investment in decentralized energy solutions; Legacy regime supports distribution networks that “lock-in” use of traditional fuels/bulk power supplies; DER/microgrids not factored into utility least-cost determinations/planning/operations; Lack of dispute mechanisms; Uncertainty surrounding development and permitting processes; Lack of standard operating procedures, quality/health/safety standards;

**Financing Hurdles:** Different risk/return equation than for traditional infrastructure; Design of subsidies to address initial costs have not led to self-sustaining investments; Lack of financial support for “Middle” business development stage; Uniform tariff and payment methods not adequate; Higher costs of capital; long payback periods.

## **BARRIERS AND RISKS**

**India's Programs take a "Legacy" Approach to "Rural Electrification"/Grid Extension, not reflecting the changing energy landscape recognized in India's "Roadmap;"**

**"Electrification" needs to be defined consistently in on-grid and off-grid programs to assure access to reliable power flows through grid extension or alternative delivery schemes; not a 10% electrification criterion that focuses solely on installation of hardware;**

**A legal definition of "Microgrids" is needed, one that is based on functions and that is consistent with India's "Model Smart Grid Regulations;"**

**MNRE Rural Electrification supports development of "Minigrids": Minigrid system is comprised of generation and distribution, operating at or below 11 KV, which addresses multiple loads in a limited area (either as a standalone system or one connected with the grid); Remote Village Electrification Program seeks 10,000 Renewable-based minigrids over 5 years, each with a capacity of from 10 KW up to 500 KW; "Microgrids" are a subset of Minigrids, having RE-based generation capacity of below 10 KW and provide direct current.**

**MOP's Decentralized Distributed Generation scheme under its RGGVY grid extension program supports isolated "minigrids."**

**Lack of Alignment and Harmonization of Programs at Federal, State and Local Governmental Levels, resulting in overlapping and uncoordinated initiatives.**

# Microgrid “Dynamic” in Power System Reform and Rural Electrification

## Challenges

- Natural Utility monopolies ; Command and Control
- Lack of enabling regulatory, institutional and market environments
- Financing clean efficient DER/Microgrid Infrastructure different than traditional generation/power systems
- Lack of education and skills
- Requires community participation
- Very small “microgrid” systems not economically viable
- Tendency to extend legacy grid
- Commercial development versus public responsibilities and obligations
- Commercial returns on investment and true pricing

## Opportunities

- Building more resilient, adaptive and transactive power systems; Inform and Motivate
- Shifting to more decentralized systems, recognizing smart microgrids as essential building block within a transformed power system
- Different risk/return equation for Energy Integrated Systems; New co-benefits/efficiencies; Catalyze local energy and economic development
- National, state and local public and private programs
- Develop community-based models for distribution systems (co-operatives; community boards for “microgrid” developments)
- Scalability, Grid-Interconnection, Power Market Access, Local Energy Networks
- National, provincial microgrid authorization plans; Develop incentives for 500kW to 40MW sustainable community projects
- Scale to type, functions, ownership and obligations
- Market-based; power/information dynamic pricing

# **LEVERAGING PUBLIC SUPPORT TO ATTRACT PRIVATE CAPITAL**

**Striking a Balance between Developmental Goals and Self-Sustaining Investment:**  
Need Light Regulation and Policy Design for Bankability, Scalability and Sustainability;

**Supporting New Intelligent Distributed Energy Management: “System of Systems,”**  
incorporating energy efficiency, renewable energy, smart grid at each developmental stage to grow productive enterprises with energy access;

**Building a “Policy Eco-System” Bottom Up and Top Down: Addressing Three to support Microgrid Market Development for economically and ecologically viable rural electrification:**

- **Policy, Regulatory, Institutional, Governance**
- **Technical Standards, Quality Assurance, Resource Assessments and Workforce Training**
- **Financial Interventions, Innovation and Market Development**

# **REGULATORY SUPPORT FOR MICROGRIDS**

## **(Addressing Market Gaps/Failures)**

**New “Integrated Grid” Paradigm:** Recognizing and Monetizing C/B of Distributed Resources, Microgrids and Energy Efficiency;

**Building a “Smart” Microgrid Business Model for Intelligent Distributed Energy Management** (Risk Management, Scale and Network Development);

**Enabling regulation for SPPs, SPDs based on size not sufficient, need support for Microgrids and Distributed Networked Electricity Systems as alternative delivery systems;** accommodate new electricity networks where more cost-effective than traditional delivery infrastructure;

**“Macrogrid Ready”: Legacy or Integrated Grid?**

- Legacy Grid Extension: Dismantle or Relocate Distribution Assets or Solely Generate Power;
- Integrate Local Energy Networks into Modernized Grid (Planning and Preparation for Interconnection/Grid compatible; Utility Distribution “Franchises” linked to local economic productivity/FIT – PPA to support commercial viability;
- Functional Units of Electric Value Chain; Address “Dark” UDC feeder lines;
- Alternatively, institutionalize Rural Cooperatives.

# REGULATORY SUPPORT FOR MICROGRIDS

**Governance Frameworks and PPP Structures** – Flexibility needed relating to ownership/management to encourage investment; Community Options/Village Power Board (public and private members); Microgrid Ownership and Management (DBOOM – Development Company, Management Company, SPV; Clarify roles under different ownership and governance structures;

**Linking Microgrid Investment to development of Productive Community Enterprises:** System design and operation to impact tangibly economic development; integrate resources and future requirements to support demand growth and generate income;

**Secure Tenant Anchors to Assure Demand and Support Growth:** Public Institutions (Municipal facilities, health clinics, hospitals, industrial and agricultural sites, etc.), Telecomm Towers (PPAs)

**Tariff/Rate Design:** Move towards cost-reflective pricing to assure cost recovery and return on investment, as well as achieving developmental goals; Tariffs based on market conditions and cost structures with community buy-in/energy-based tariffs; Could index price to next alternative electricity source or provide reverse auctions under common parameters and commercial principles; Need more consistency and transparency in application for business planning;

# REGULATORY SUPPORT FOR MICROGRIDS

## Designing Public Subsidies to Manage Transition to Self-Sustaining Investments

- Currently targeted at initial technology installation to keep tariffs affordable to customers, but not O&M;
- Subsidies that complement tariffs need to be adequate, disbursed in a timely manner and set minimal bureaucratic hurdles;
- Combination of capital and generation (FIT) subsidies advisable;
- Designing “Performance-Based” Subsidies to assure O&M; disbursement mechanisms results-based to incent continued use, operation, maintenance with M&V.

**“Transactive” Business Models:** “Pay as Go”/Prepay; Tradeable/Market-Based Energy Block Tariff and Accounting Model with declining subsidy; TERI Solar/Microgrid Modular Units; Network Microgrid Cells (Resource Integration and Energy Sharing)

**Siting, Business Registration/Licensing and Permitting:** Requirements scaled to size and functional characteristics; reasonable in terms of duration, specificity and other conditions for approval; Striking balance between assuring reasonable service at affordable costs for customers and facilitating investment and reducing transactional costs for developers (structure to “scale” of utility service); Appropriate regulations help provide means for establishing technical and financial relationships with state and central higher voltage utilities; Consolidate into one set of standardized procedures business registration, registration for subsidies, land purchase and environmental assessment; Specifically authorize microgrid/network development within “off-grid” designated zones.

# **TECHNICAL STANDARDS, RESOURCE ASSESSMENTS, PILOTS AND HSC**

**Technical Standards** (Safety, Reliability, Energy Security, Health, Environmental Quality) “size” to fit scale, complexity of functions and operations, market conditions; Support adequate supplies of equipment from manufacturers and vendors for timely maintenance, repair and replacement; Standardize system/control specifications;

**Quality Assurance Framework and Business Codes**, striking balance between quality and cost to support demand growth and community engagement;

**Human, Social and Cultural Best Practices (HSC)** – Capacity-building, Training and Education of Village as Manager, Employees and Consumers

- Aligning Business Model with Community’s Vision, Aspirations, Resources, Culture
- Design Process: Community Engagement, Design, Deployment, Utilization/Operations
- Increasing Productivity of Livelihoods and Local Economies
- HSC Teams by Donors and Government Agencies
- Codes of Ethics



# TECHNICAL STANDARDS, RESOURCE ASSESSMENTS, PILOTS AND HSC

**Pilots/Demonstrations:** Setting Baselines, Quantifying Costs and Benefits, EM&V; Lessons Learned; **Model Smart Grid Regulations** to reflect “Vision and Roadmap” Targets; USDOE/MOST RD&D Consortium under PACE/CEM;

**Resource Assessments: Development of Local Banks** targeted at high impact areas for siting and construction; Regional resource assessments generate data regarding available resources, locations and renewable power generation potential for locations, energy demand, load variances; Facilitate Regional Smart Microgrid Development;

**Cost-Effective Technology Platform:** Evaluate Cost structures of different combinations of technologies in light of local resources and circumstances to provide high quality, affordable and reliable electricity for lighting, communications, water supply, motive power and other services;

**Grid Interconnection Standards:** Streamlined/published grid-interconnection standards and islanded operation standards to reduce uncertainties surrounding central grid extension and to assure safety and security of both central and microgrid; Detail financial costs, technical standards and tariff setting.

# **MARKET DEVELOPMENT: FINANCIAL INTERVENTIONS AND INNOVATIONS**

**Three Forms of Interrelated Financing: Governmental Financial Incentives and Public Subsidies, Debt/Equity Financing from Banks and Investors, Customer Tariffs from ratepayers and Power Purchase Agreements from off-takers and other revenue streams; Lack of Long-term financing stems from uncertainties surrounding return on investment and revenue streams (“bankability”**

**Programmatic Changes for Standardizing and Streamlining Project Development Process**

- **Standardize Criteria for Bankability of Investments; Prequalification criteria**
- **Standardize Measurement and Valuation: Performance Metrics, Benchmarking, C/B Analytical Frameworks;**

**Moving Toward Cost-Reflective Pricing and Tariff Structures;**

**Smart Grid Agenda: Align Demonstration Program with Smart Grid Vision and Roadmap and Incorporate Rural Electrification Demonstrations using smart microgrids to address energy access and availability; Development of an “Integrated Grid”**

**Align Federal, State and Local Rural Electrification Programs under Vision and Roadmap; Networked Microgrid Cells** allow villages to be clustered for a bundled infrastructure approach using standardized architecture, reducing overall costs, which could be spread across villages;

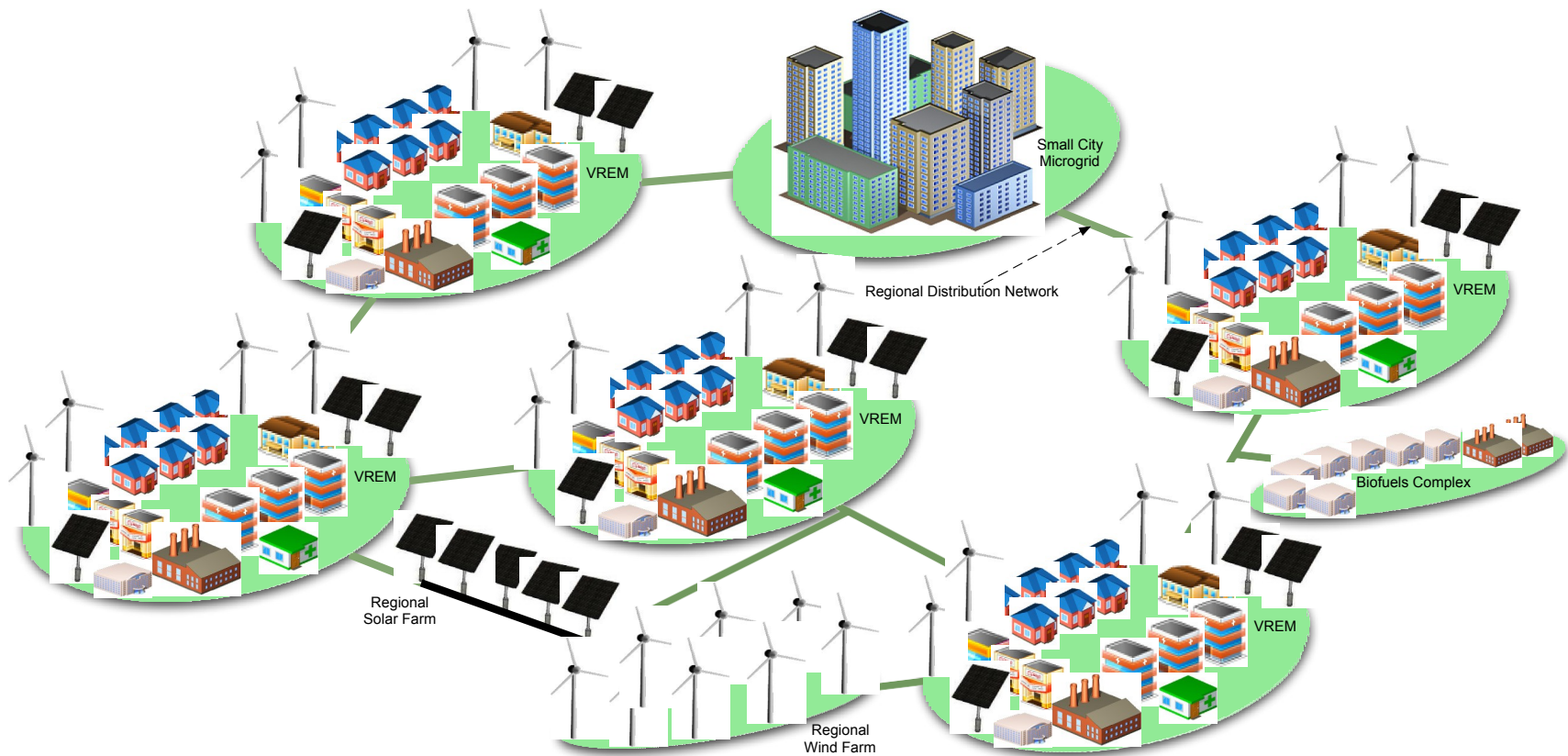
# **MARKET DEVELOPMENT: FINANCIAL INTERVENTIONS AND INNOVATIONS**

**Building Solid Partnerships Vertically and Horizontally:** Rural Electrification Corporation, State Nodal Renewable Energy Development Agencies, Public Sector Organizations, Rural Energy Service Providers; Federal Agencies (MOP, MNRE, BIS, CEA, FOR, etc.), Financial Institutions (NABARD/IREDA/RRB/Commercial Banks), Communities/Villages (Panchayats); SERCs and DISCOMs

**Targeting Public Support and Structuring Financing to Engage Private Commercial Banks and Investors:** Government offering output-based and performance-based grants, financing and incentives; Government-owned banks provide low interest loans to developers and interest subsidies could reduce rates for commercial loans; also, Government Institution can provide credit enhancement by guaranteeing financial institutions payment in event of default by borrower, backed up by a dedicated fund; Policies that promote smart microgrid solutions providers as a Priority Lending Sector for Indian Banks to facilitate debt financing; Promotion of Smart Microgrid Development Companies to address different facets of microgrid development;

**Bilateral and Multinational Financial Support:** Mezzanine Debt with Concessional Financing (subordinated debt to improve value of project by raising level of project equity and thus creditworthiness of project).

# Villages Can Be Networked



# Thank You

## General MicroGrids

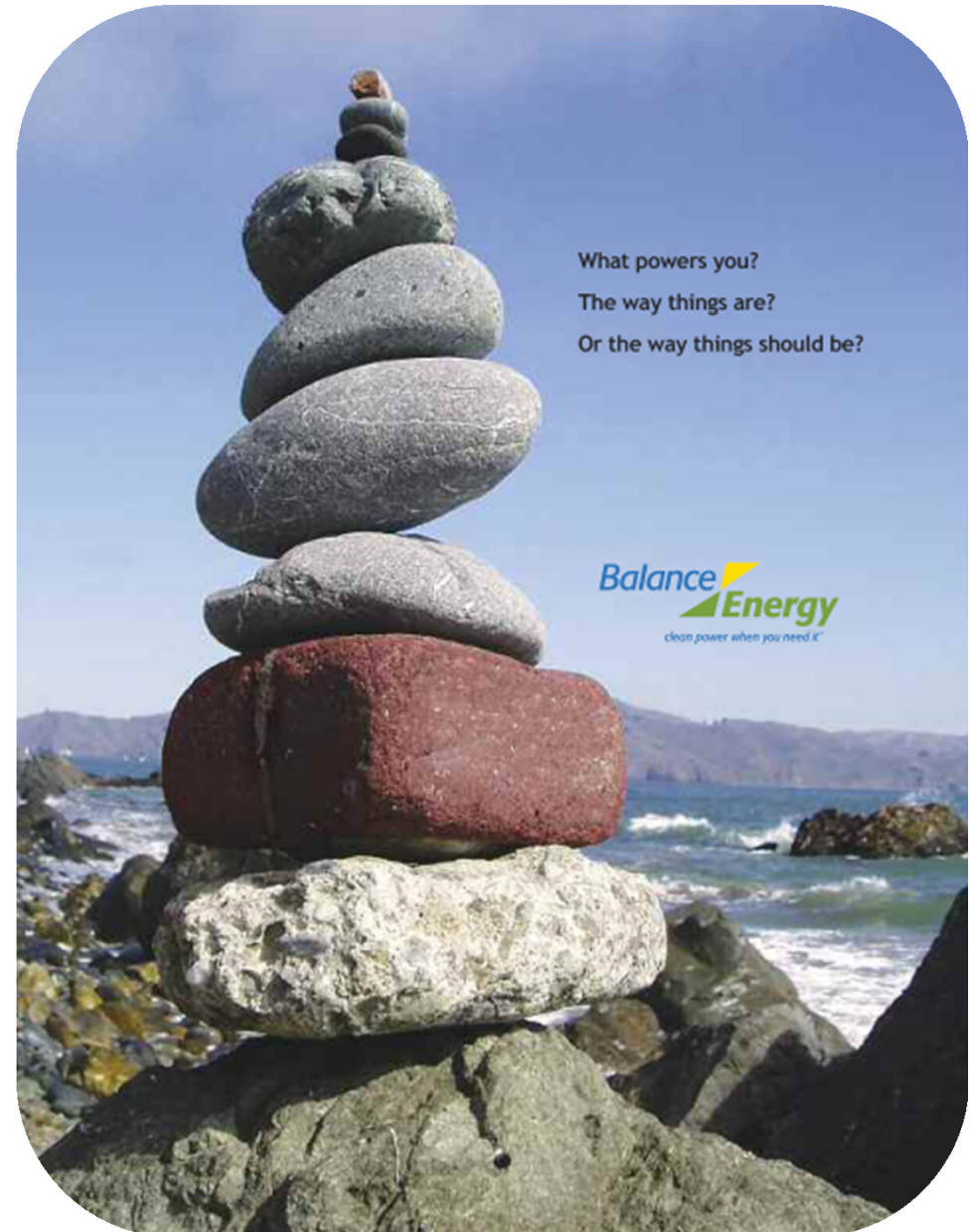
### Balancing Energy for a smarter, renewable-driven grid

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