Community as a Power Plant: Conceptualizing Integrated Energy Systems for Local Communities

RENSY | Binod Koirala | 8 Dec 2014
Learning Objectives

- Understand changing energy landscape.
  - Regional, national, local perspective
- Understand the concept of integrated community energy systems (ICES) / Community as a Power Plant.
- Evaluate ICES
- Analyse the future opportunities/ trends for ICES
- Understand developing countries perspective
Outline

• Background: Changing energy landscape
• Conceptualization of integrated community energy systems (ICES)
• Exercise: Value of integrated energy systems
• Future trends for ICES
• ICES in Developing countries
Changing Energy Landscape

Exclusive: RWE sheds old business model, embraces transition
October 21, 2013 - Author: Karel Beckman - Tags: coal power, electricity market, Energiewende, energy efficiency, grid, renewables, smart grids, wind power

RWE, Germany’s largest power producer, has decided to radically depart from its traditional business model based on large-scale thermal power production. Henceforth, the company will “create value by leading the transition to the future energy world”. This is shown by confidential strategy documents that were discussed at a recent meeting of RWE’s Supervisory Board in Warsaw which Energy Post has seen.

Photo: RWE power plant in Hamm-Uentrop by Dirk Vorderrast (Flickr)

The new strategy was decided on at a meeting of RWE’s Supervisory Board in Warsaw on 19 and 20 September. It will be discussed more broadly within the company in video conferences scheduled for 20 October. RWE is one of Europe’s biggest emitter of greenhouse gases.

The “Strategic Roadmap” discussed in Warsaw and a strategic document called “RWE’s Corporate Story” make it clear that the company’s leadership has accepted that RWE, which has traditionally relied heavily on its coal-fired and nuclear power production business, has decided that it needs to radically change course if it wants to survive in the new energy world created by Germany’s and the EU’s Energiewende. “The massive erosion of wholesale prices caused by the growth of German photovoltaics constitutes a serious problem for RWE which may even threaten the company’s survival”, states the Strategic Roadmap.

At the same time, RWE’s management has decided that the company will not be able to play a leading role in the new growth sector of decentralized, subsidized power production, which it says will remain “the only growth segment in the European power generation market” for the foreseeable future. “In a low-interest environment, it will not be possible for RWE to generate sufficient return within this subsidised industry. Our cost of capital will not be competitive against funding from private and institutional equity investors”, says the strategic document.

E.ON stakes future on renewables with fossil spin-off

By Andrew Lee in London - Monday, December 01 2014

Updated: Monday, December 01 2014

German utility giant E.ON today geared its future around renewable energy by announcing a radical corporate restructuring that will see its conventional generation assets spun off into a new company.

The split will see E.ON focus on three core businesses – renewables, networks and customer solutions – while its conventional generation, energy trading, and exploration and production businesses are transferred to the new entity, as yet to be named.

It told shareholders: “E.ON will place a particular emphasis on expanding its wind business in Europe and in other selected target markets. It will also strengthen its solar business.”

CHALLENGE THE FUTURE

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Challenge the future
Changing Energy Landscape

- Increasing fossil fuel scarcity
- Climate change concerns
- Technological change
- Liberalization and restructuring of energy sector

> Radical transformation at local energy landscape
Changing Energy Landscape

Existing
Upcoming

International Grid

National Grid

High Voltage
Medium Voltage
Low Voltage

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Changing Local Energy Landscape

- Local generation
- Self-organised energy communities
- Energy systems integration
- Electrification of different sectors (heat pumps, EVs)
Changing Local Energy Landscape

**Local Generation**

- PV
- Micro-wind
- Combined heat and power
- Fuel Cells
- Heat Pumps
- Bidirectional power flows
Changing Local Energy Landscape

*Self-organized energy communities*

PHOTO BY: RUDOLPHO DUBA/PIXELIO.DE
Changing Local Energy Landscape

*Self-organized Energy Communities*

(Bauwens, 2013)
Changing Local Energy Landscape

Energy Systems Integration

Resources and Generation
- Solar
- Wind
- Intermittent Electricity
- Geothermal
- Biomass
- Fuel Cells etc
- Fuels (gas, oil, biomass)
- Waste Heat
- Intermittent Heat
- Solar Thermal

Storage and Exchange
- Grid Power Exchange
- Electricity Storage
- Cold Storage / Exchange
- Heat Exchange
- Heat Storage
- Fuels Storage

Demand
- Electricity
- Cooling
- Heating
- Mobility

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Changing Local Energy Landscape

*Electrification of different sectors*

- Heat pumps
- Boilers
- EVs
- Threefold increase in household demand
- Enforcement of power lines or different form of organization?
Exercise

Discuss in group of 4-5 students. Which option you prefer and why? What are the challenges in the chosen option?

• Reinforcement of local grids
  OR
• Different form of organization (Integrated Community Energy Systems, Capacity management)
Conceptualizing Integrated Community Energy Systems (ICES)
Introduction

*Conceptualizing Integrated Community Energy Systems (ICES)*

adapted from Geelen et al., 2013
Introduction

Conceptualizing ICES

Exchange with energy system (electricity, gas and heat)

ICES

Flexible Generation

Intermittent Generation

Storage

Demand Response

Demand

Match
Introduction

*Conceptualizing ICES*

- Micro-generators (fuel cells, CHP)
- Heat pumps
- PV /Micro-wind/ Solar-thermal
- Electric vehicles
- Storages
- Appliances
- Smart meter
- Time variable prices, contracts
- Home energy management system

Community energy management system

Household level

Community level

National grid

adapted from Geelen et al., 2013
Introduction

Community Engagement

- Local Generation
- Collective Purchasing
- Local Balancing
- Demand response
Introduction

ICES Actors and Institutions

**Actors**
- Households
- Communities
- DSOs
- ESCOs
- Energy Suppliers
- Aggregators
- Intermediary Organizations
- Government Organizations

**Institutions**
- Government policies
- Dominant technologies
- Organizational routines
- Industry standards and specialization
- Societal expectations and preferences
- Flexible regulations
- Centralised -> Self- governance
- Flat rate -> Dynamic pricing
- Support schemes, incentives
- Network access
- ...

TU Delft

Challenge the future
Introduction

Roles and Responsibilities

- DSOs
  - Grid operation and management
- Aggregators
  - Aggregation of Flexibility
- Integrated Community Energy System (Community as a Power Plant)
  - Business Models
  - Local Markets
  - Local Balancing
  - Electricity Prices
  - Flexibility
  - Energy Management
- Prosumers
  - Local Generation
  - Demand Response
  - Collective Purchasing
  - Energy Management
- End-users
  - Demand Response
- Consumers
ICES as Complex Socio-Technical Systems
Key Issues

**Technical**
- Available technologies
- System integration vs. Autarky
- Local balancing
- Flexibility
- Energy mix (local/national)

**Socio-economic**
- Community engagement
- Economic incentives
- Energy poverty
- Security of supply
- Financing

**Institutional**
- Trust, motivation and continuity
- Energy democracy
- Ownership model / co-operative
- Support schemes
- Self-governance
- Regulatory issues
- Roles and responsibilities

**Environmental**
- CO2 emissions
- Spatial / noise issues
Demonstration Project

SEC Heerhugowaard

- 250 Households
- 80 heat pumps
- 80 boilers
- 10 Fuel cells
- 200 PV + Switches
- Grid Exchange
Calculation: Value of Integrated Energy System for a Household
# Valuation Indicators

<table>
<thead>
<tr>
<th></th>
<th>Valuation Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical</strong></td>
<td>Power and energy balance, system efficiency, renewables penetration</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Price, production cost, life cycle cost</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>Accessibility, affordability, dependency</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>GHG emissions, noise, space use</td>
</tr>
</tbody>
</table>
Electricity Demand
PV + Demand
Power Balance

![Graph showing Power Balance over 24 hours with peaks and troughs.]
PV + micro-wind + CHP
Power Balance
Power Balance comparison
Electricity Price
Valuation Indicators: Results

<table>
<thead>
<tr>
<th>Valuation Indicators</th>
<th>Reference Case</th>
<th>Case 1 (PV) (PV+Wind+CHP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Balance</td>
<td>- Demand</td>
<td>Slide 28</td>
</tr>
<tr>
<td>Energy Balance</td>
<td>-28,8 kWh</td>
<td>-13.56 kWh +0,28 kWh</td>
</tr>
<tr>
<td>Renewable Penetration</td>
<td>0</td>
<td>0.53</td>
</tr>
<tr>
<td>Price (daily)(^a)</td>
<td>5.53 EUR</td>
<td>3.025 EUR 1.08 EUR</td>
</tr>
<tr>
<td>Dependency</td>
<td>1</td>
<td>0,65</td>
</tr>
<tr>
<td>GHG emissions (^b)</td>
<td>12.5 kg</td>
<td>8.01 kg 5.65 kg</td>
</tr>
</tbody>
</table>

\(^a\): feed in tariffs of 10 euro cents/kWh, \(^b\): emission factors for grids (NL) 0.435 tCO2/MWh, emissions factor for natural gas: 0.202 tCO2/MWh
Interested to scale these results for Integrated Energy Systems for Local Communities?

- Master thesis offer:
  - Unleashing the technical, economic, social and environmental value of Integrated Community Energy Systems
  - Assessment of demand and supply-side flexibility from Integrated Community Energy Systems
Future Trends

- Energy sufficiency
- Scalability
- Local markets / beyond markets
- Grid defection
- Trends in developed, emerging and developing economies
Developing Countries Perspective
Interconnected Mini-grids for Rural Energy Transitions
A Case of Nepal

RENSY | Binod Koirala | 08 Dec 2014
How applicable is following system boundaries for developing Countries?

![Diagram of energy system boundaries]

- **National Energy System**
  - Electricity: Solar Photovoltaics, Wind, Biomass/Biogas, Geothermal, Hydro, Fuel Cells, Diesel Generators, CHP
  - Storage (electric, cooling, heat)
  - Energy Demand, Energy Efficiency, Demand Response, Flexibility (Local Balancing), collective purchasing
  - Community, Ownership, Institutions and Markets

- **Integrated Community Energy System**
  - Heat: CHP, Local heating system, Heat pumps, Waste heat (industries)

- **Electricity Network/Grid**
  - Mobility (EVs, Hybrid, conventional)

- **Gas/Fuel Network**

**Challenge the future**
Community Micro-hydro in South and South East Asia

- 600 million without electricity access
- Most of them rural
- Community micro-hydro
  - 154 MW total
  - 1.3 million households
  - However, only 1% of population without access
- Problems in scaling up
Problems in scaling up

https://www.youtube.com/watch?v=rm57rdrLIK4
https://www.youtube.com/watch?v=KMKdan_RjEU
Background - Nepal

- Per capita energy consumption: 14 GJ / NL 211 GJ
- Per capita electricity consumption: 120 kWh / (NL 6800 kWh)
- Total installed capacity: 800 MW, demand 1400 MW
  - Severe energy crisis in Nepal
    - 30 % population has no access to electricity
    - Upto 16 hours of load-shedding in National Grid
Background- Nepal

• In Rural areas,
  • Long grid expansion time
  • More than 3000 isolated micro hydro plants !!
  • Only two Interconnection realized so far
    • Baglung Mini-grids and Gulmi Mini-grids
Why integrated solution?

• Major problem faced by Micro Hydro
  • Low load factor (around 20%), reliable services
  • Lack of integrated plan for rural electrification
  • Grid expansion has created great threat to MHPs
  • NEA being sole grid operator shows unwillingness to connect MHP into Grid
  • Peak load problems
  • Low contribution in socio-economics improvement
What we can be done...

Improve energy access?

Improve grid stability and quality?

Improve Socio-economics?
Create business opportunities and multiplier effects?
Integrated Approach

- Integrated approach helps to
  - Optimize Electricity Generation from MHP
  - Reduce the possibility of abandonment of MH after grid interconnect into national grid
  - Improve socio-economic through productive use
  - Support local infrastructure and economic development
Project site - Baglung

Pre/ detail study: 2006/2007
Commissioning: 2011
6 MHPs from same river Kalung Khola-107 kW
Benefitted HHs-1200
PLC based control system
Business Model: IPP

- MG Cooperative is responsible for the transmission and distribution of electricity
- Each MHP function as IPPs generate electricity
- Power Purchase Agreement (PPA) (buying US cent 5.3/unit and selling: USD 8.82 for 12 unit and 8.2 cent/unit afterwards)
- Local ownership on individual plant and mini-grid as well
Performance Evaluation

• Technical
  • Quality, Availability and Reliability of electricity improved
  • Easier starting for motor and bigger load
  • Better safety & protection
  • Plant factor doubled (17 to 34%)

• Economic
  • Increment of MHPs income by 20 to 60%
  • Income of Entrepreneurs increased by 5 to 30%
  • New Enterprise established (33 to 52)

• Social
  • Community confidence level has increased-empowered
  • Behavioral change in electricity use (lighting to productive end use)
  • Sense of ownership and unity among community
  • Easy for consensus decision and resource mobilization (water rights, right of way, human and financial resource-40%)
Project site - Gulmi

Wamitaskar, Gulmi, Western Nepal

Daram Khola MHP
(85 kW, 760 HHs)

Paropakar MHP
(135 kW, 1004 HHs)

28° 11’ 27.28 N, 83° 17’ 05.50 E
763 m
Paropakar MHP

- Forebay
- Headrace
- Turbines and generator
- Power house and transformer
- Power house
- Tailrace of Paropakar and inlet of Daram
Daram MHP

Power house

Turbines and generator

Monitoring System

Point of interconnection seen from Daram
Daram Khola MHP: Generation and

- Overloaded
- Flickering
- Load shedding (peak hours)
- Solution: Interconnection
What happens to excess energy?

→ Energy Management System? Productive Use?
Vision

Renewable Based Interconnected Mini-Grids

- Daram MHP
- Income generating activities
- Wind
- PV
- Parcpakar MHP
Exercise

• What similarities and differences you observed in integrated energy systems for Local communities in developed and developing countries?
Evaluation of Learning Objectives

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Thank you very much!
Questions and Discussions!

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