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Polygeneration of cooking fuel, electricity, and drinking water on the community level

Andrew Martin – *Department of Energy Technology*

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Outline of Presentation

- Background
  - Principles of membrane distillation (MD)
  - KTH-led MD investigations
- Bangladesh case study
- Recent and future activities

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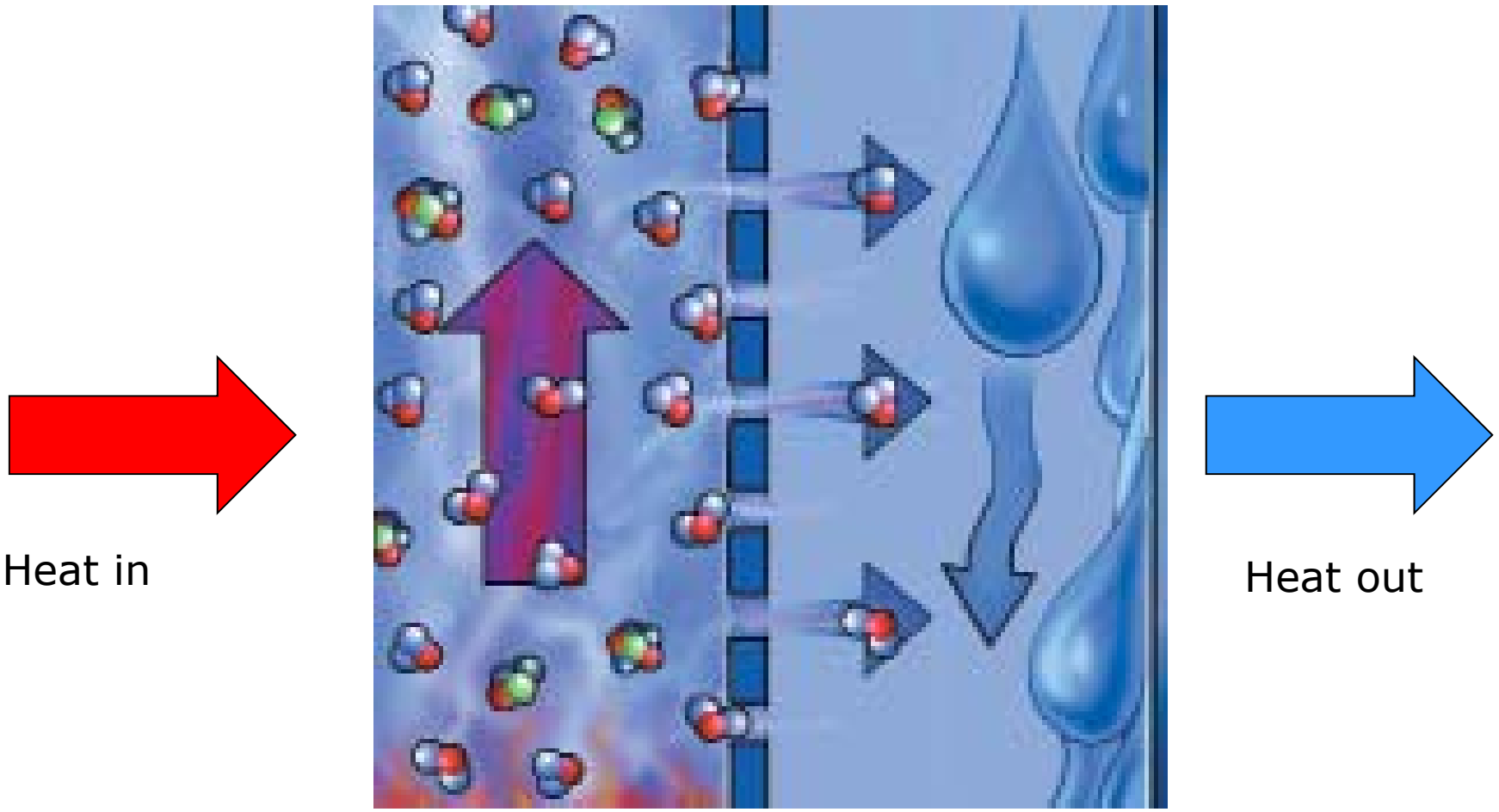
Background on MD

- Reverse osmosis (RO) widespread technology for treatment of
  - Boiler makeup water, DH network water
  - Flue gas condensate
  - Desalination
- Membrane distillation (MD) is a promising alternative to RO:
  - Utilizes low-grade heat contra electricity
  - Robust operation
  - (Possibly) less sensitive to process fluctuactions

Principles of MD



Courtesy of Scarab Development AB

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Advantages of MD

- 100% (theoretical) rejection of ions, macromolecules, colloids, cells, and other non-volatiles
- Lower operating temperatures than conventional distillation
- Lower operating pressure than conventional pressure-driven membrane separation processes
- Low sensitivity to variations in process variables (e.g. pH and salts)
- Good to excellent mechanical properties and chemical resistance
- Potentially lower capital costs as compared to RO

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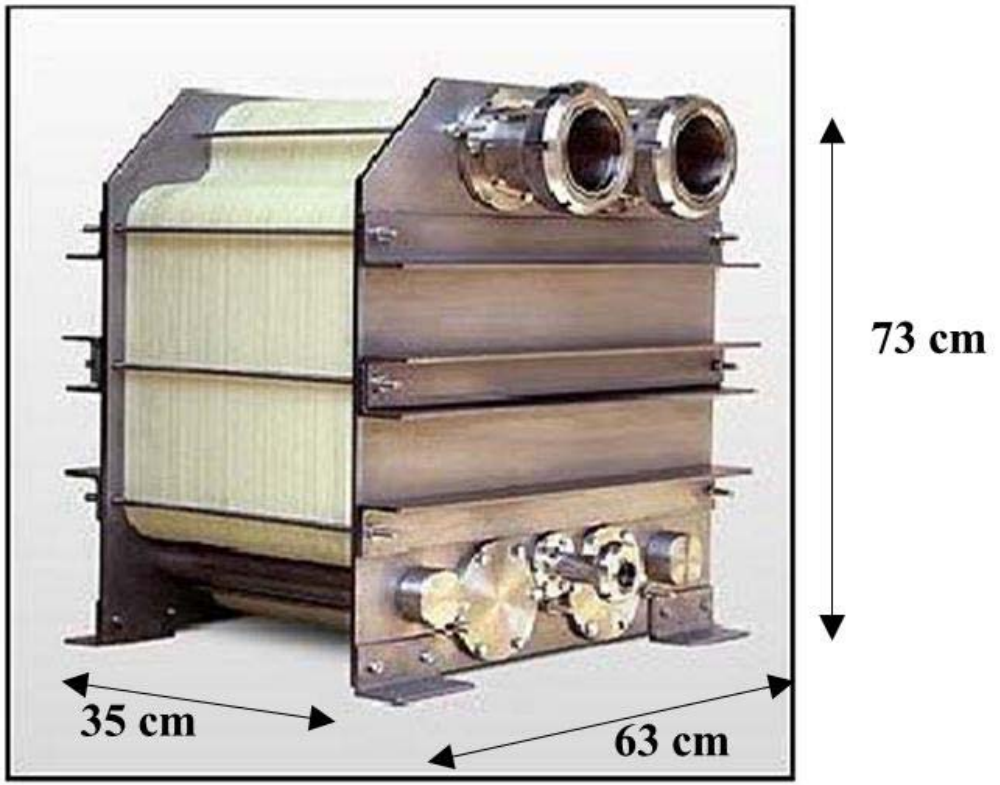
Drawbacks of MD

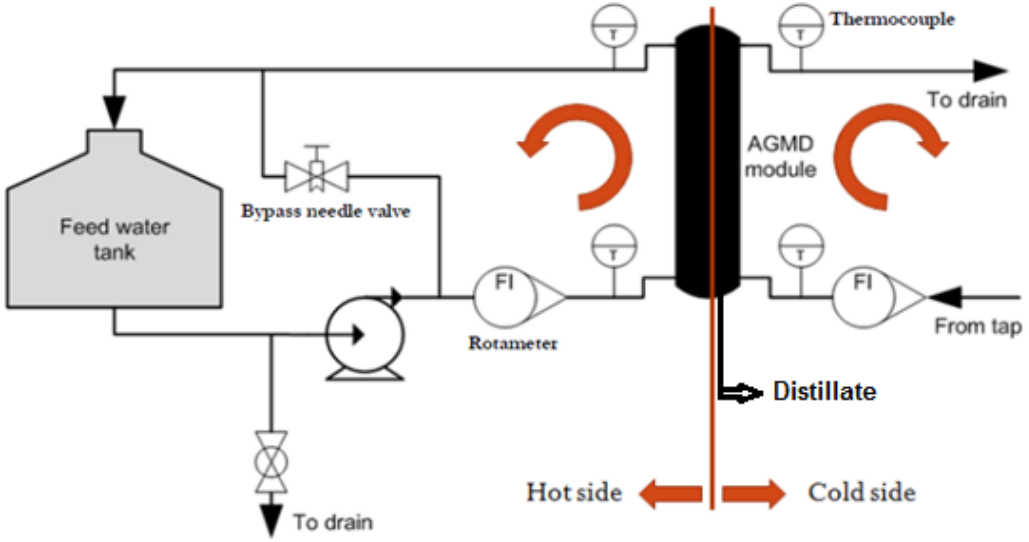
- High energy intensity (although heat is usually low grade)
- Low yield in non-batch mode; high recirculation rates in batch mode
- Sensitive to surfactants
- Volatiles cannot be completely separated (degassing or other methods required)
- Not yet commercially available

Scarab semi-commercial AGMD module

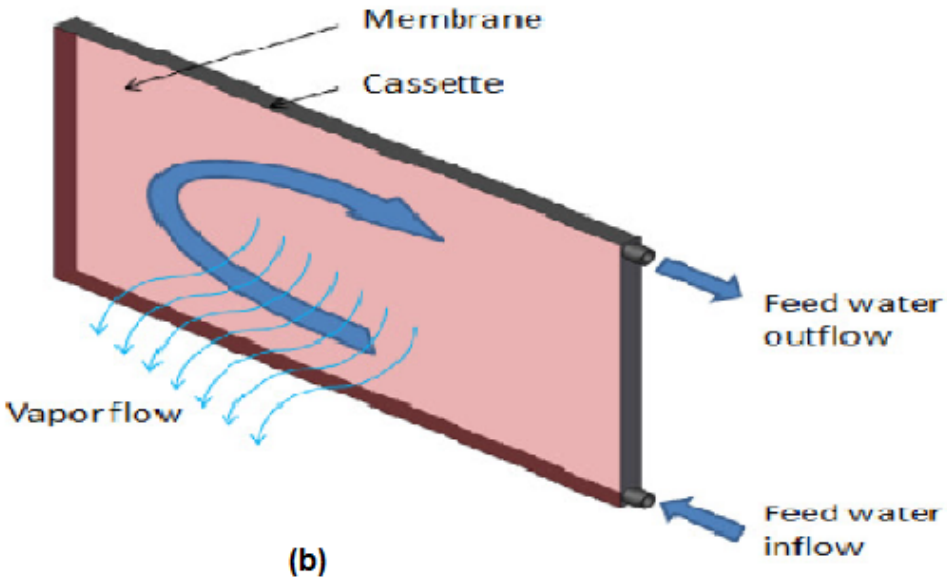
- Plate and frame arrangement
- 10-25 cassettes/module
- 1 mm air gap
- Membrane data:
  - PTFE
  - 2.3 m^2 (10 cassettes)
  - Porosity 80%
  - Pore size 0.2 μm



1-2 L/hr/module range



(a)



(b)

- Plate and frame arrangement
- 1 cassette
- Membrane area: 0.2 m^2
- Feed flowrate: 3-5 L/min
- Hot side *T* 70-80°C

Water quality analysis of arsenic spiked tap water

Parameter	Unit	Concentration in arsenic spiked feed water	Concentration in distillate
As	µg/L	300	<0.03
Ca^{2+}	mg/L	50	<0.7
Mg^{2+}	mg/L	12.5	<0.02
Na^{+}	mg/L	100	<0.17
K^{+}	mg/L	5	<0.03
Conductivity	µS/cm	250	0.6-1.5

analysis conducted by Activation Laboratories Ltd, Ontario CA

Water quality analysis for arsenic contaminated Bangladeshi well water

Parameter	Unit	Concentration in ground water	Concentration in distillate
Arsenic (As)	µg/L	334	< 1.0
Manganese (Mn)	mg/L	0,102	0.001
Phosphate (PO4)	mg/L	3,28	0.03
Electrical Conductivity	µS/cm	845	98
TDS	Mg/L	270	0
pH		7.5	6.5

analysis conducted by BUET, Bangladesh

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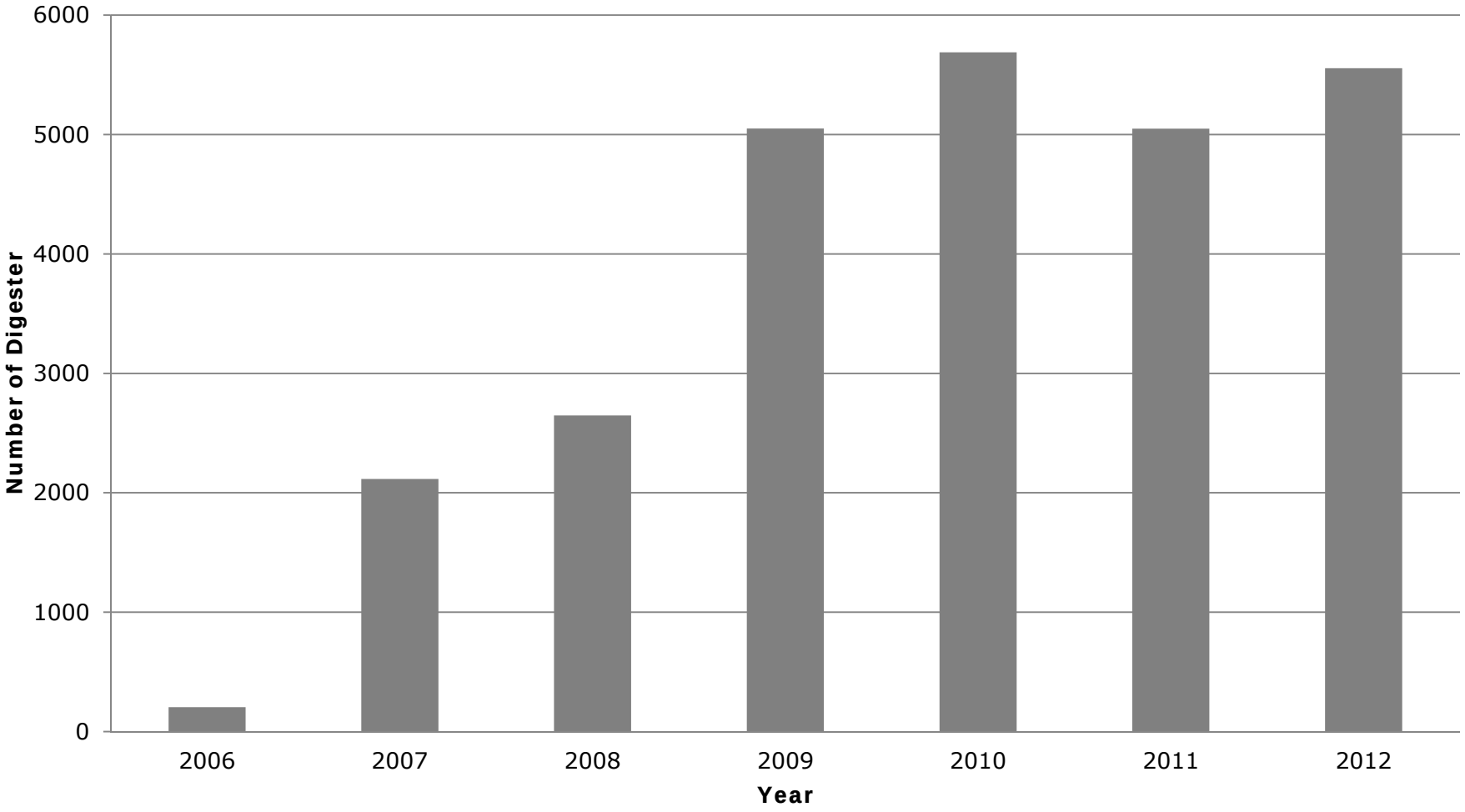
- **Bangladesh case study**

Biogas based poly-generation for rural development in Bangladesh (Access to clean energy and services) – SIDA project conducted by Prof. Semida Silveira (leader), Prof. Andrew Martin, Brijesh Mainali, Ershad Khan

- Ongoing and future activities

Use of digesters widespread in Bangladesh



S. Islam, IDCOL (2009)

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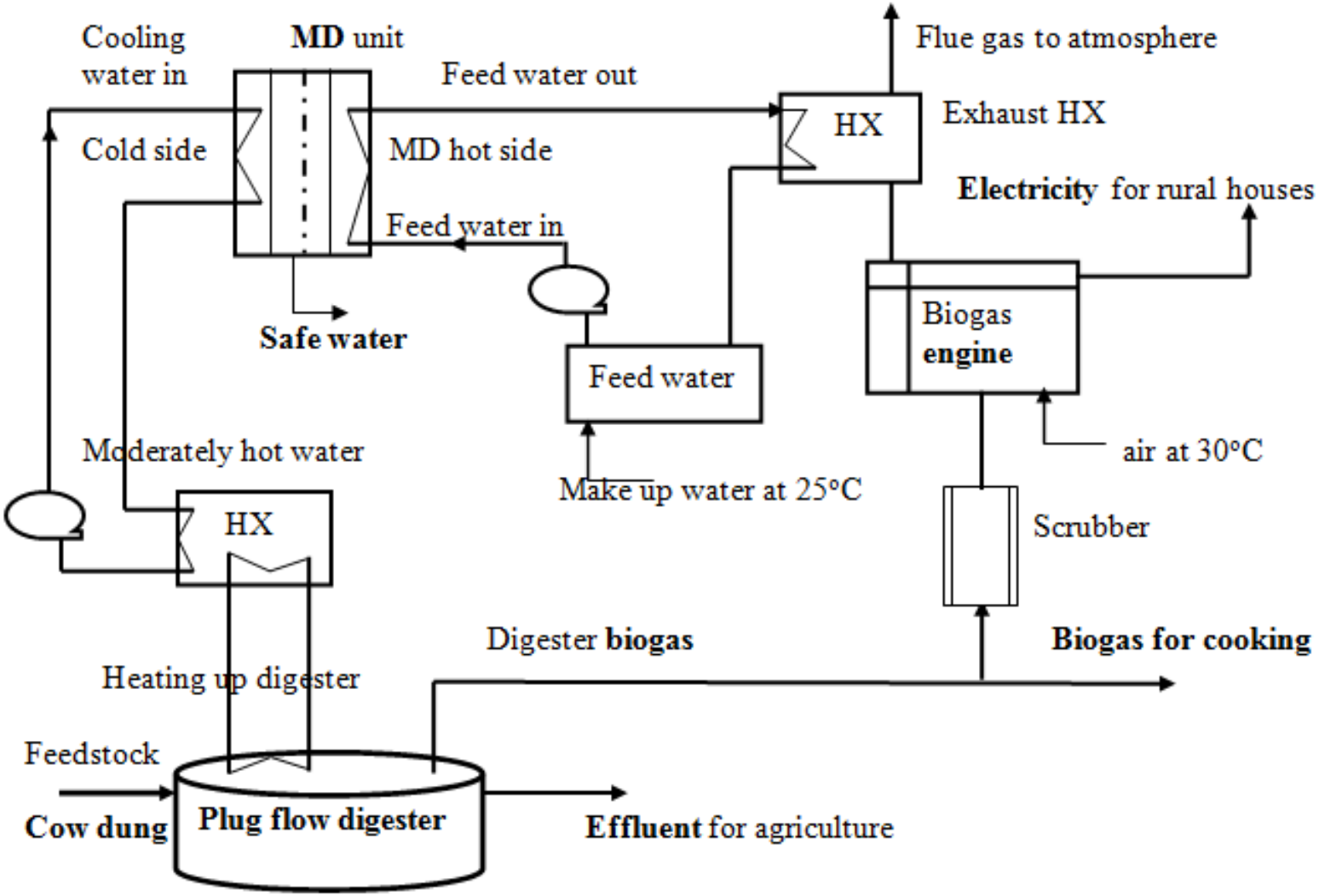
Design for a village of 30 Households

Description	Assumptions
Average family size	5 person per HH
Avearge household electricity demand	27 kWh /Household/month
Cooking energy need	0.3 m^3 of biogas/meal/person
Drinking water need	3 liters/person/day

Energy and mass balance for integrated system



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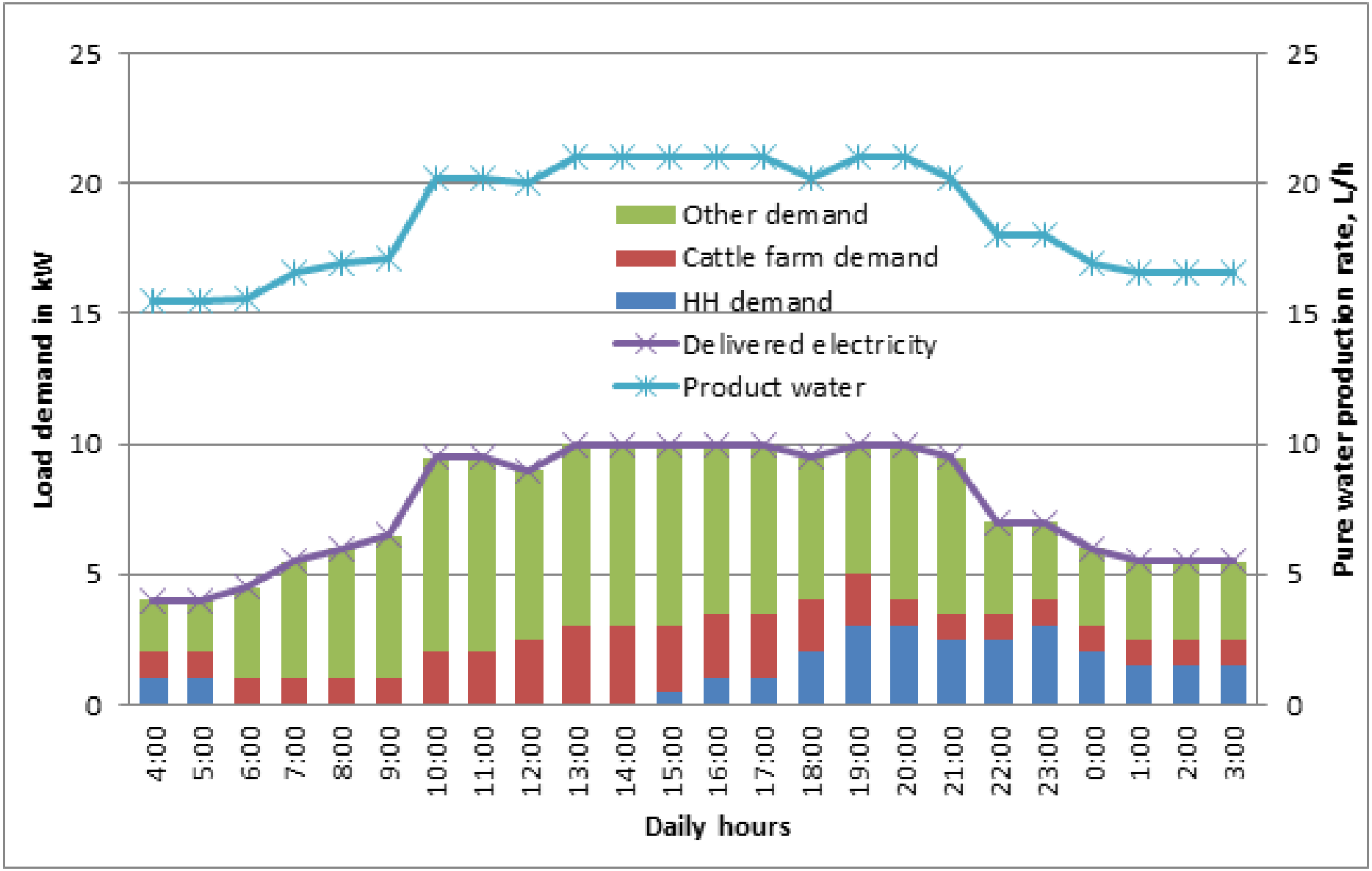
Daily load and demand curve



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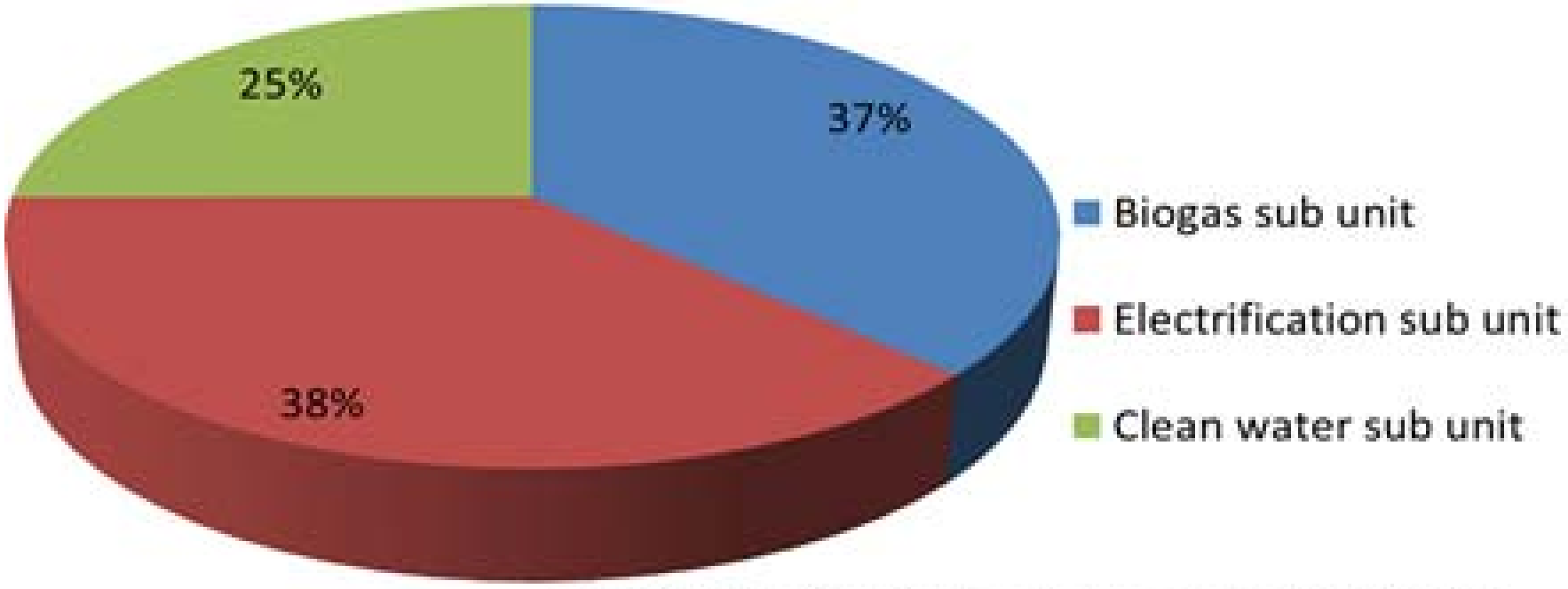
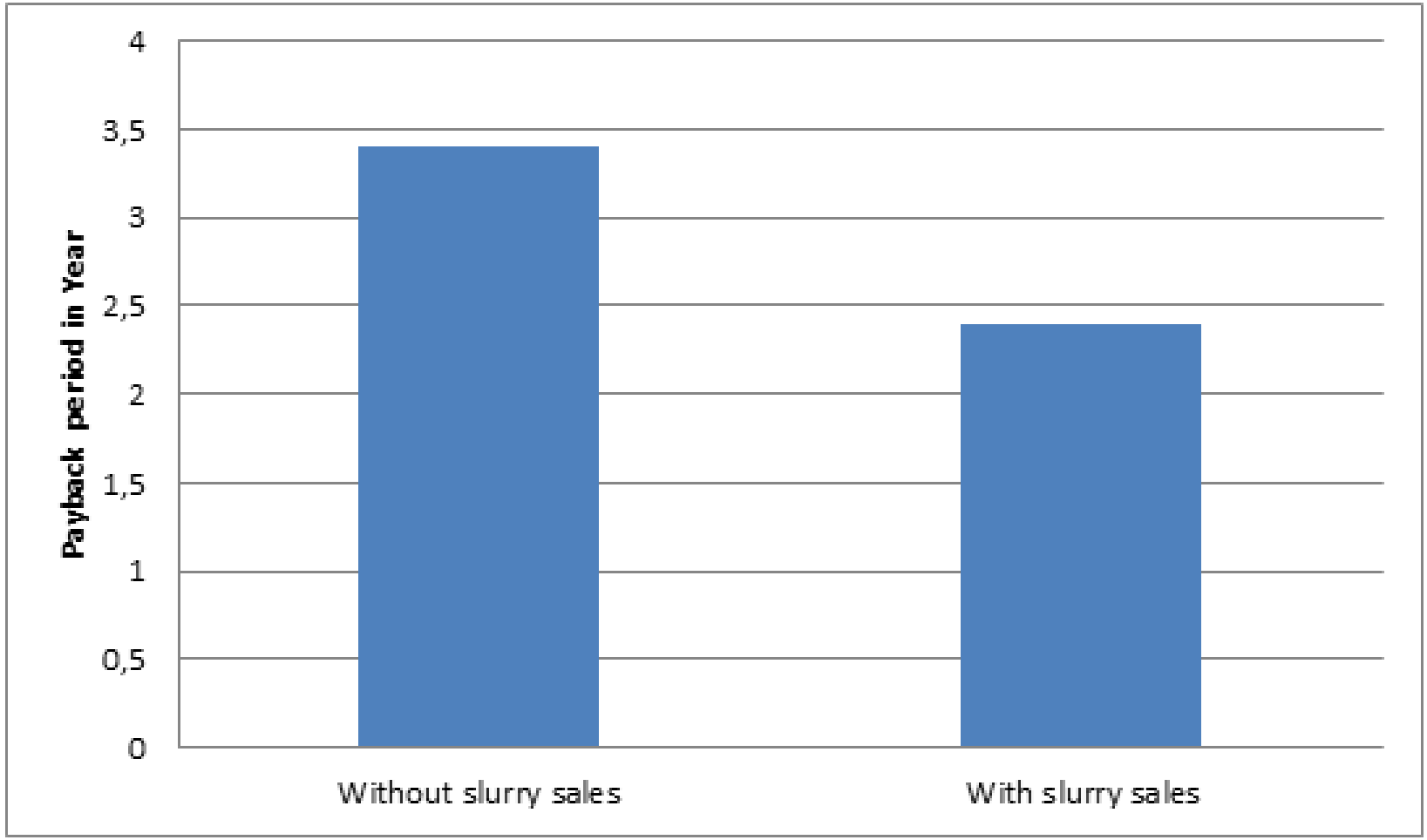
Estimated capital cost



Total Cost of the integrated system USD 26050

Payback period



el $0.073/kWh; biogas $10/HH/mo; water $0.005/L; slurry $24/tonne

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Recent Project Activities

- Visit to Bangladesh (Mainali), July 2012
  - Seminar with stakeholders
  - Biogas workshop

- Arsenic Workshop in Bangladesh (Khan), Dec 2012

- Minor Field Studies

  Hassan Ahmed

  Nashrin Akter

  Caroline Saul

Stakeholder Consultation

40 participants from 24 different organizations including governmental, non-governmental, donor organization, private companies and plant owner owners

B. Mainali

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Key Findings

- Poly generation project has been appreciated by most of the stakeholder in the consultation process.
- If the model is well designed, this can shift the paradigm of providing rural services.

Existing sector's strength

- Pre-qualified, competitive partner organizations
- POs have large network across the country
- Strong micro-finance based

Biogas based electrification option as an alternative during the case of load shedding.. **RE Policy 2008**

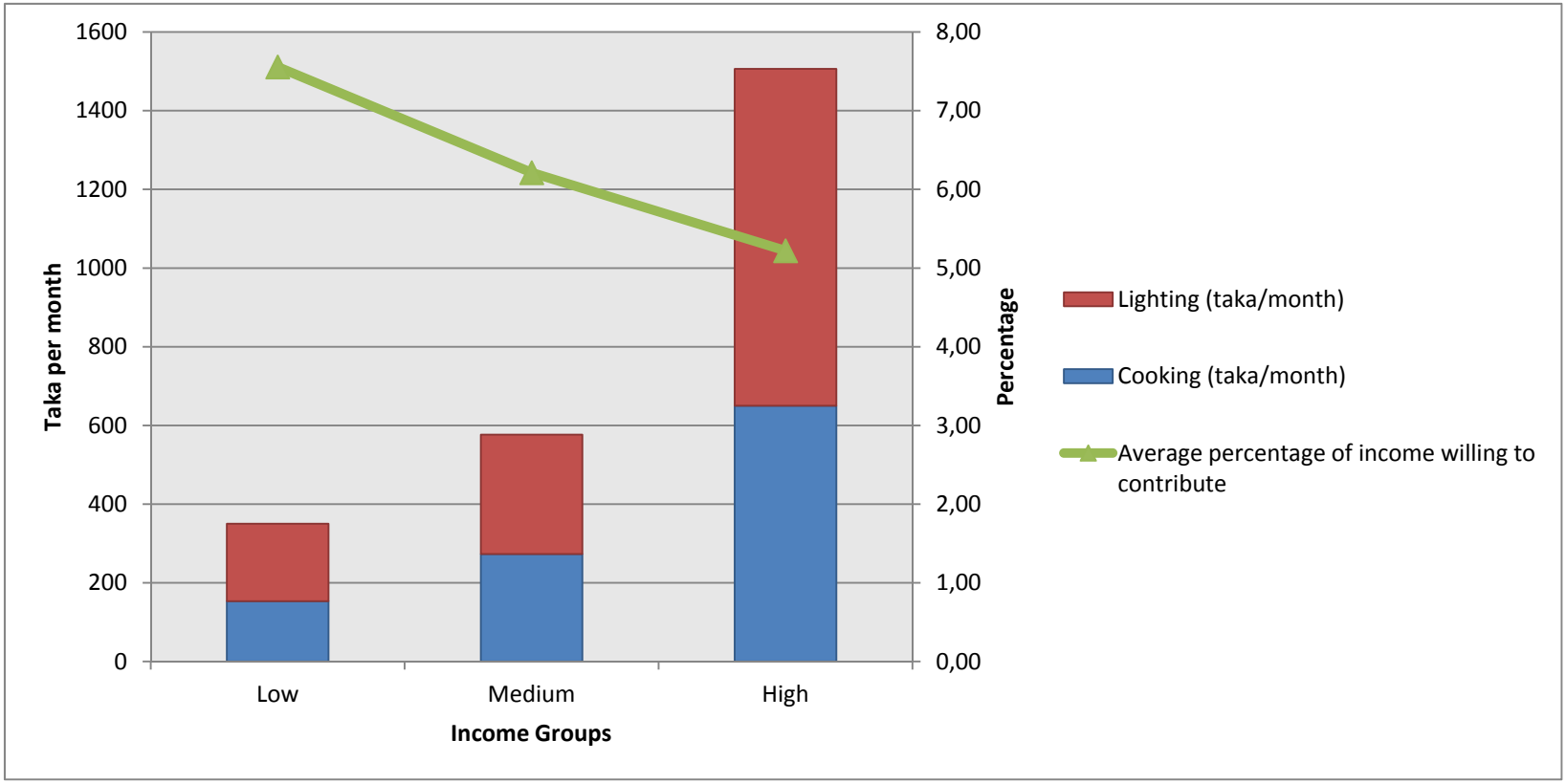
Project aim:

The main stream supply source meeting the cooking energy need, electricity and the water demand…

Ability to pay (field survey results)

Willingness to pay for lighting and cooking facilities:

- Increase in amount with higher income level
- Decrease in average percentage of income willing to spend with higher income



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Future Activities

- SIDA project will continue until end of 2014
- Demonstration facilities key

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Selected Publications

- Chuanfeng Liu and Andrew Martin. 'Applying Membrane Distillation in High-Purity Water Production for Semiconductor Industry,' *Ultrapure Water*, April (2006.
- Chuanfeng Liu and Andrew Martin. 'Membrane Distillation and Applications for Water Purification in Thermal Cogeneration – A Pre-study,' Värmeforsk report nr. 909 (2005). Available at www.varmeforsk.se
- Alaa Kullab and Andrew Martin. 'Membrane Distillation and Applications for Water Purification in Thermal Cogeneration – Pilot Plant Trials,' Värmeforsk report nr. 1029 (2007). Available at www.varmeforsk.se
- Ajay K. Manna, Mou Sen, Andrew R. Martin, and Parimal Pal. 'Removal of Arsenic from Contaminated Groundwater by Solar-driven Membrane Distillation,' *Environmental Pollution*, 158 (3), pp. 805-811 (2010).
- Alaa Kullab and Andrew Martin. 'Membrane Distillation and Applications for Water Purification in Thermal Cogeneration Plants,' *Separation and Purification Technology*, vol. 76, no. 3, pp. 231-237 (2011).
- Alaa Kullab. 'Desalination Using Membrane Distillation: Experimental and Numerical Study,' PhD Dissertation, Royal Institute of Technology (2011).
- Ershad Ullah Khan and Andrew R. Martin, Water Purification of Arsenic-contaminated Drinking Water via Air gap Membrane Distillation, submitted to *Periodica Polytechnica.*
- E U Khan, B Mainali, A R Martin, and S Silveira, Techno-Economic Analysis of Small Scale Biogas Based Polygeneration Systems: Bangladesh Case Study, draft paper under review.

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Tack så mycket – Thank You!