A simulation tool to design PV-diesel-battery systems with different dispatch strategies

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Agenda

- Motivation
- Our hybrid energy tool
  - Models
  - Dispatch strategies
  - Designing tool
- Simulation example
- Conclusion and perspective

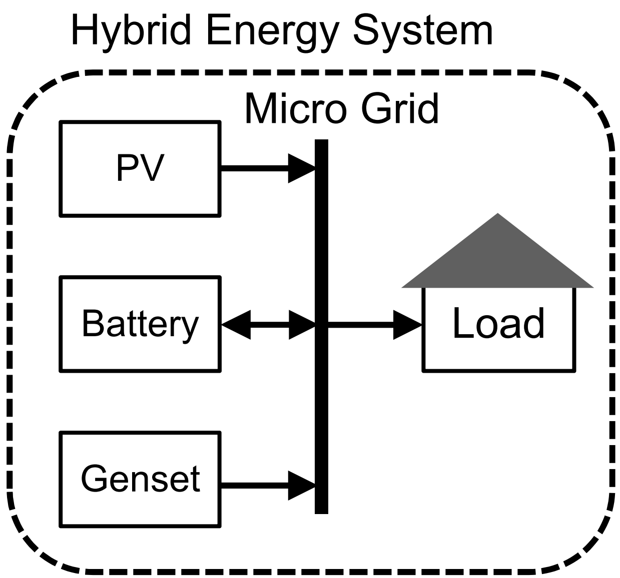
Motivation

- Electricity in remote areas is often supplied by diesel generators
  - They are often expensive (fuel costs) and emit CO_2
- Renewable energy sources can improve profitability and reduce CO_2-emissions
- But: part-load ranges below 50% and sudden load steps on diesel generators can reduce lifetime and higher emissions [1]

Motivation

- Common hybrid energy simulation tools:
  - Technical detailed simulation [2] [3]
  - Feasibility studies [4]
  - Multifunctional tools [5] [6] [7]
    - Easy to use
    - dispatch, design and economic functions
    - Optimization by genetic algorithm

Motivation



- Purpose for our tool
  - Simulation of PV-diesel-battery systems
  - Easy-to-use
  - Realistic simulation models
  - Smart dispatch strategies

- Model simulation in MATLAB Simulink and system design simulation in MATLAB GUI

MATLAB [8]

Our hybrid energy tool – models

- PV: Double-diode-model [9]
  - Considers physical behavior, i.e. the I-V-Values of solar cells
  - Combined with a MPP-Tracker
- Battery: Shepherd-model [10]
  - Battery charging depending on cell voltage and state of charge (SOC)
  - Experimental measured discharge curves can be applied
    - Currently only lead-acid battery can be applied

Our hybrid energy tool – models

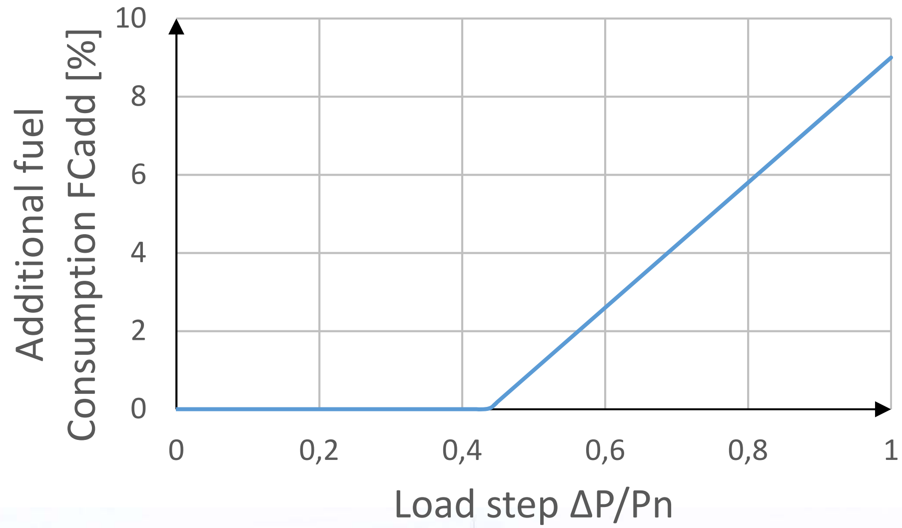
- Diesel generator: advanced model
  - Part-load dependent fuel cunsumption based on break specific fuel consumption (BSFC) [11]

Add-on:

  - Load step dependent fuel consumption based on field tests with a small genset (5 kVA)

$$FC_{add} = \left(0.16 \cdot \frac{|\Delta P|}{P_n} - 0.07\right) \cdot FC_{stat}$$

with FC_{add} = Additional fuel consumption in liters
FC_{stat} = Static fuel consumption in liters
$\frac{|\Delta P|}{P_n}$ = Part load step of the generator



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Our hybrid energy tool – dispatch strategies

- Opposition of
  - reducing fuel consumption by PV power

    vs.

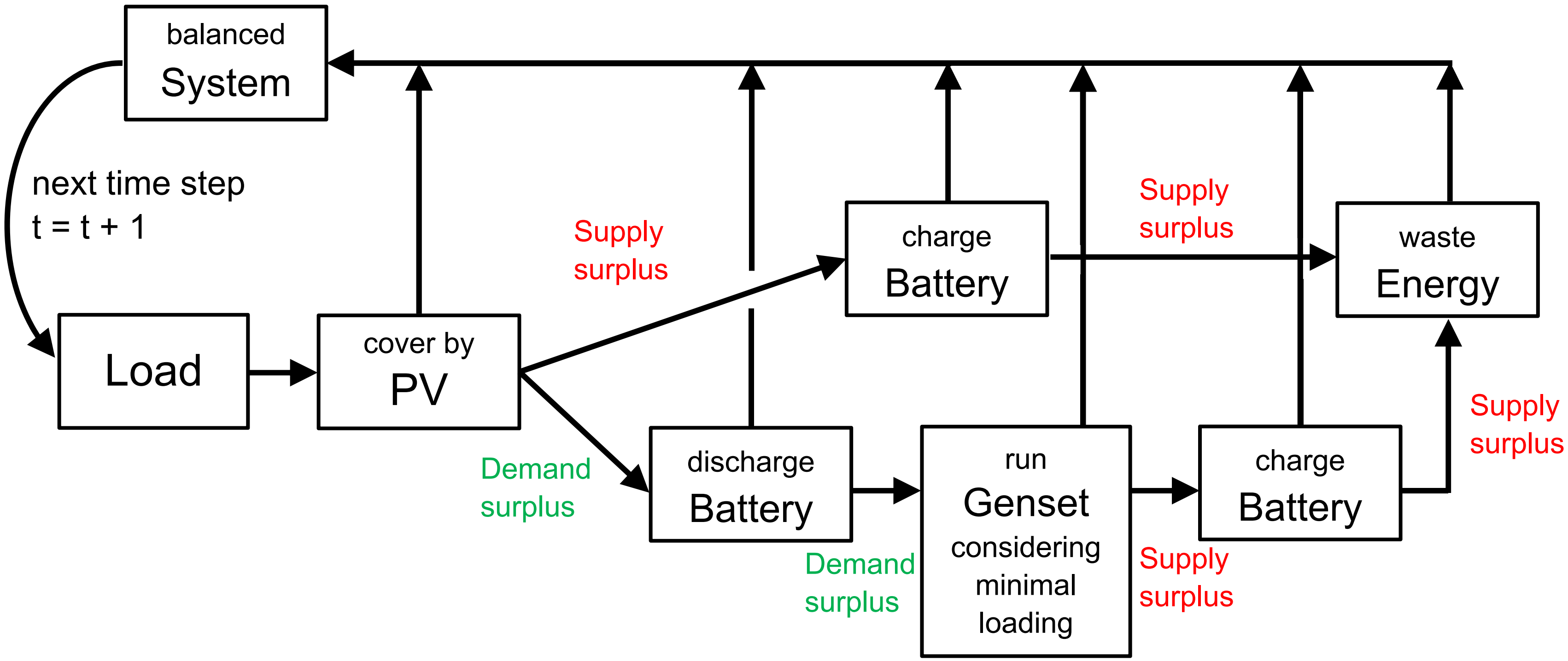
  - reducing harming effects caused by power volatility
    - Part-load ranges and dynamics of diesel generators

      vs.

    - Battery cycling and depth of decharge (DoD)

- Improve economic and ecological efficiencies of the system

Our hybrid energy tool – dispatch strategies



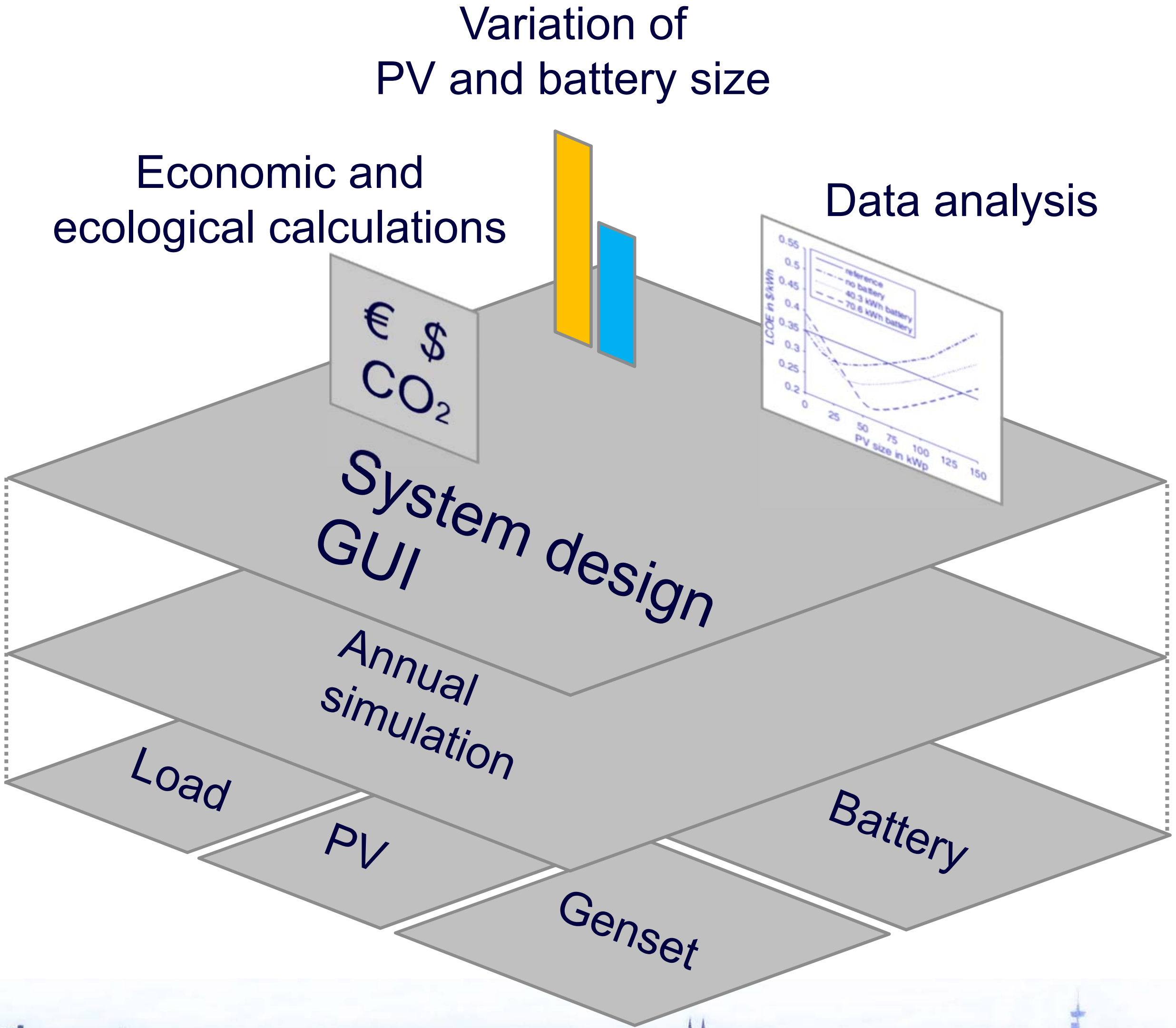
Pro:

- PV retain feed-in priority
- Gensets are preserved (min. Load)

Contra:

- Battery is also charged by gensets

Our hybrid energy tool – designing tool



Simulation example

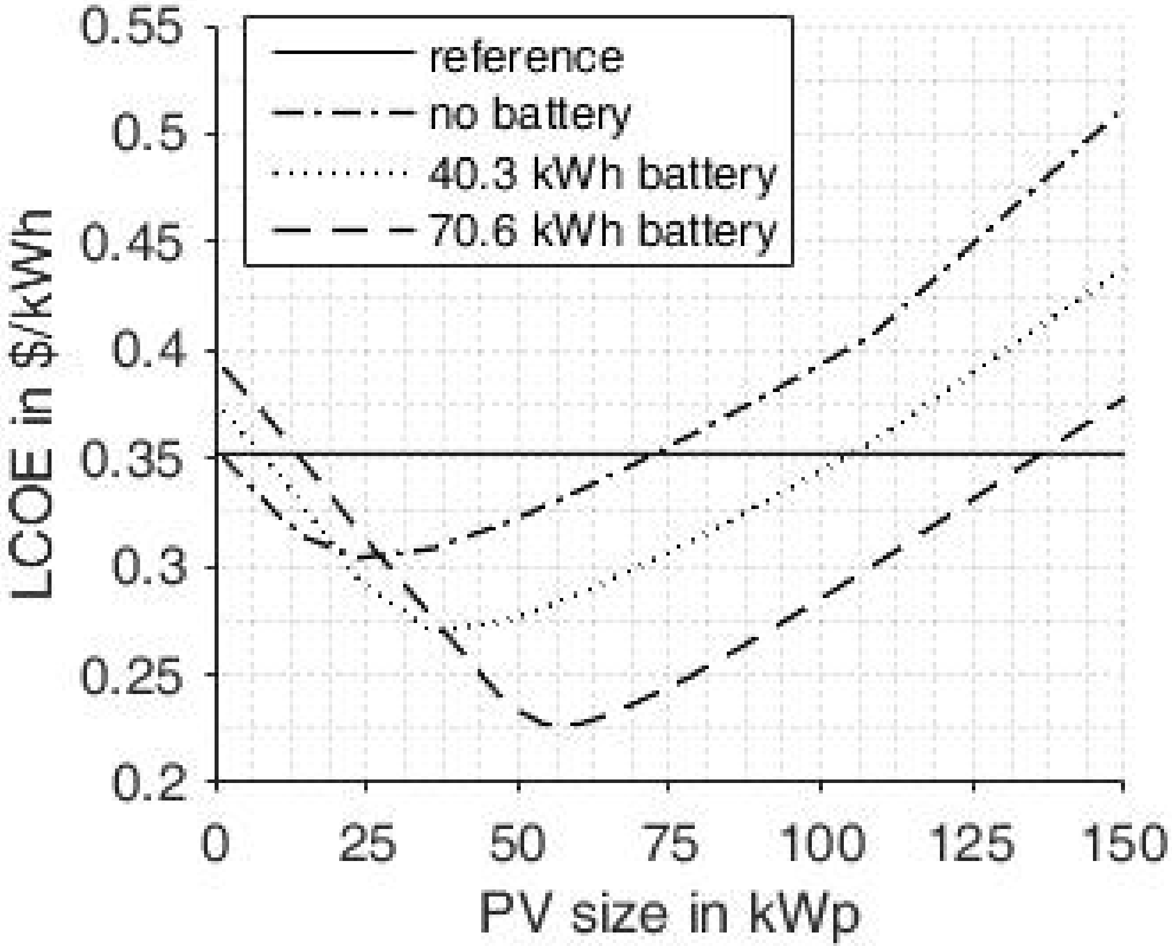
- Microgrid of community with 25 households
  - Max. 49.4 kW & 97.8 MWh/a
  - Assumption: 4 Gensets (32, 29, 12 and 4.6 kW_{el})
  - Assumption of fixed and variable Costs:

Element	Investment Costs	Maintenance Costs
PV	2,500 $\$/kW_p$	25 $\$/(kW_p \cdot a)$
Battery	760 $\$/kWh$	20 $\$/(kWh \cdot a)$
Gensets	35,000 $	30 $\$/(kW_{el} \cdot a)$

- Two diesel price scenarios: [12]
  - 0.90 $/l (world average, China, Ghana, Paraguay)
  - 0.50 $/l (Lebanon, Myanmar, Kyrgyztan, Bolivia)

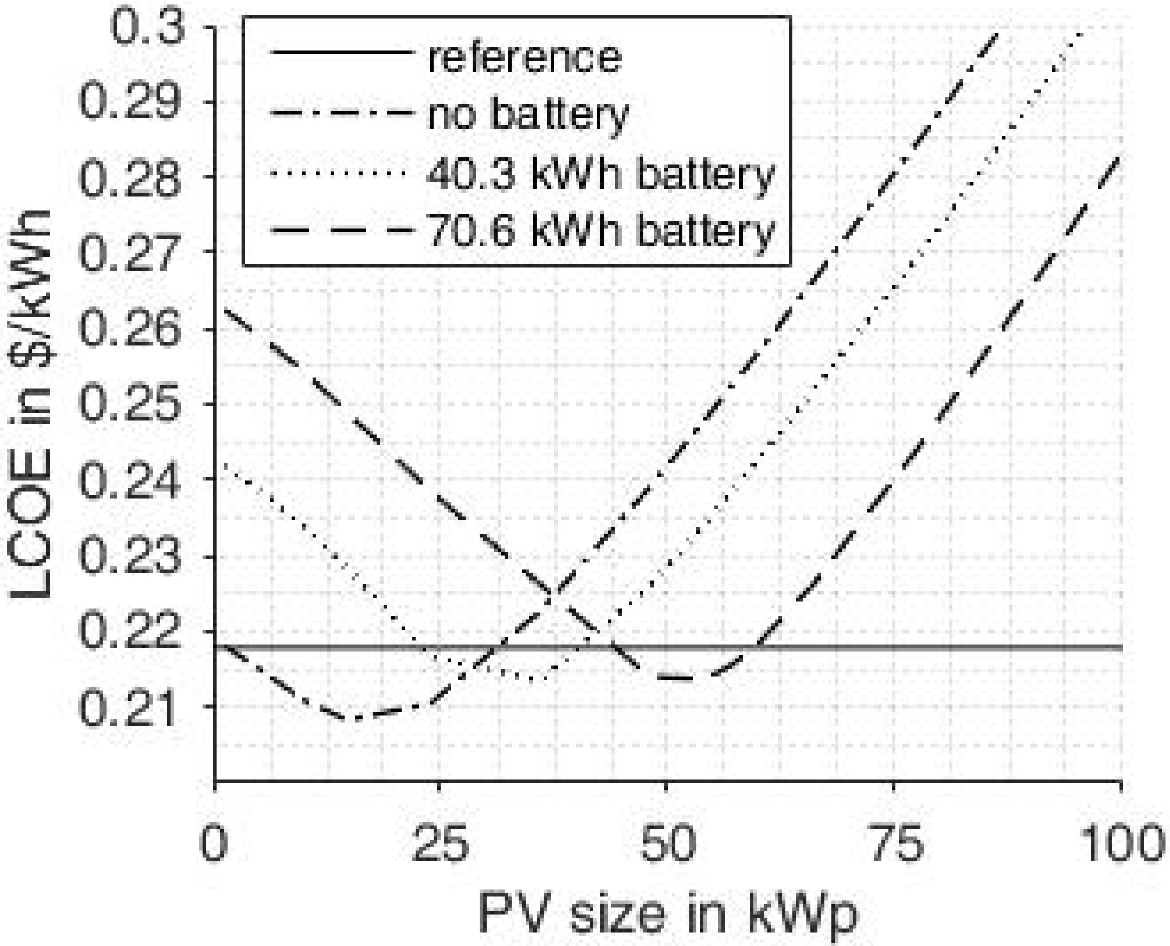
Simulation example – results

- Diesel price: 0.9 $/l

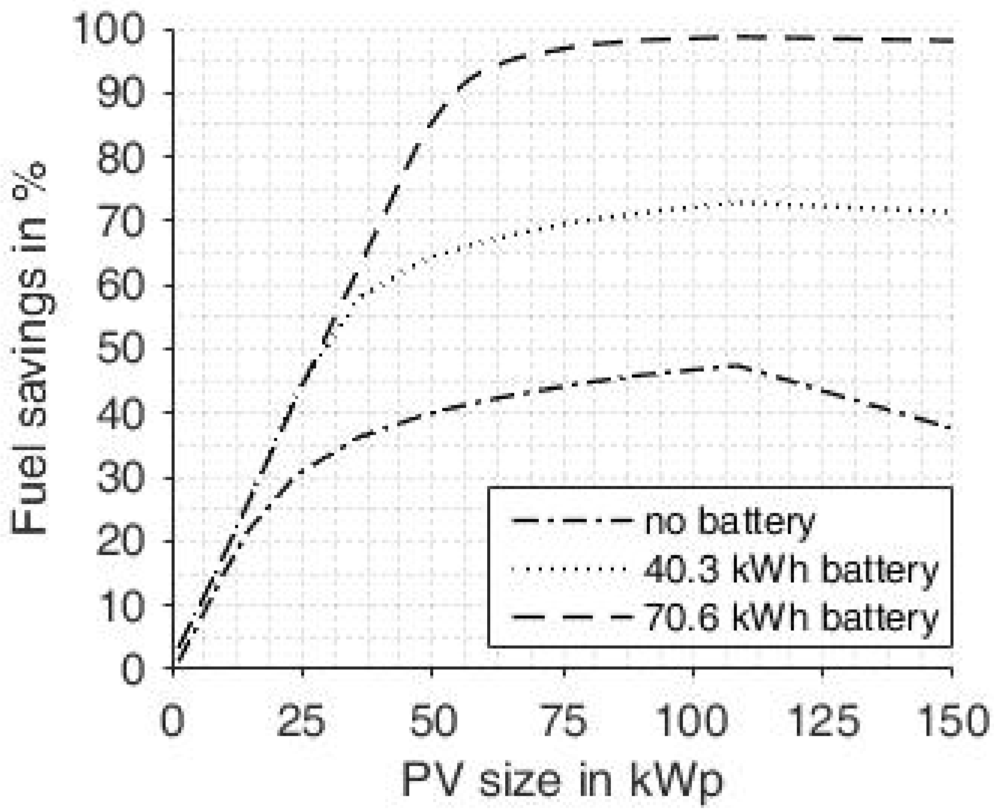


Simulation example – results

- Diesel price: 0.5 $/l



Simulation example – results



- 57 kWp PV and 70.6 kWh battery save aprox. 81 tons of CO_2 in 20 years (life time period)

Conclusion and perspective

- Developement of a hybrid energy tool with the aim on a realistic model simulation

- In the simulation example with an average fuel price 94% of fuel can be saved in the economically best case.

- Next steps:
  - automated parameter optimization
  - improvement of genset model by means of field tests with a larger diesel generator (>1 MW)

Thank you for your attention!

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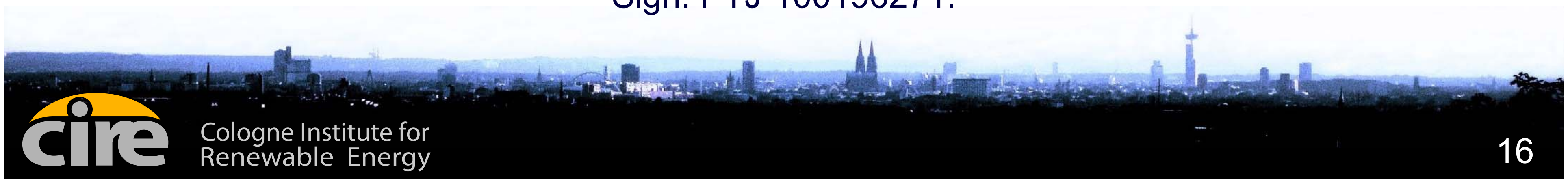

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