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# Simulation of Hybrid PV Systems

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Technology development, system design  
and performance improvement



Simon Schwunk

Fraunhofer Institute for  
Solar Energy Systems ISE

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# Overview

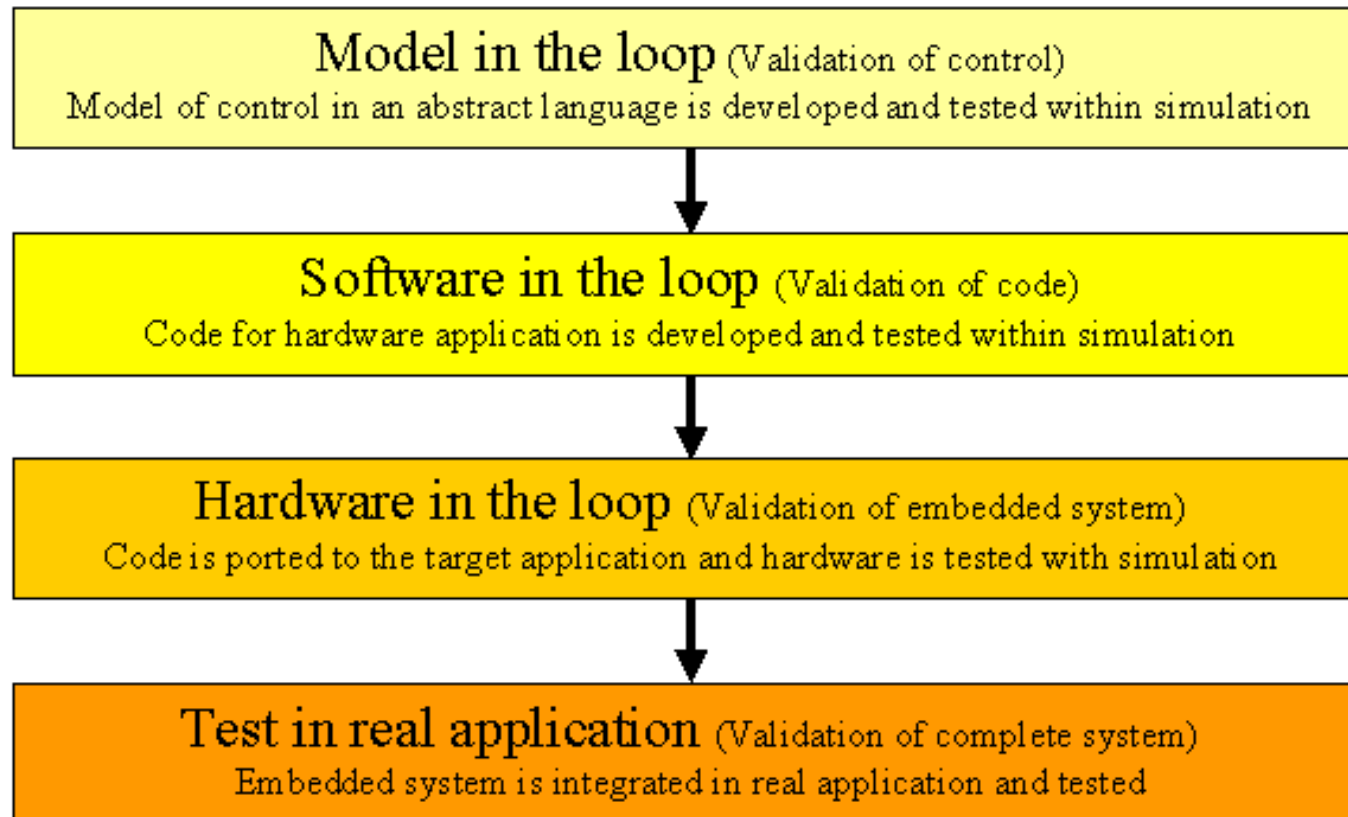
- Introduction
- Development of algorithms
- System design and sizing
- Analysis of systems
- Conclusions

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# Introduction

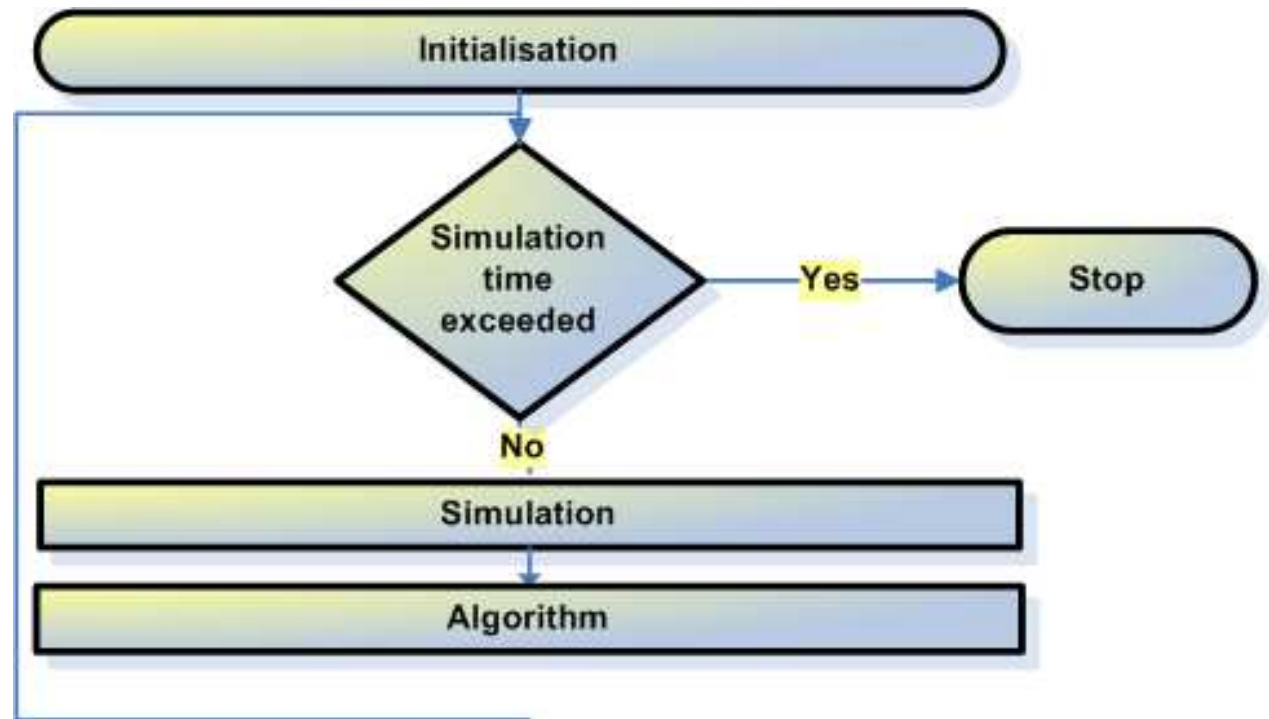
- Simulation is a tool widely used within different industries
- Main targets:
  - Saving costs
  - Speeding up development processes
  - Analysis and optimisation of technical devices and systems
- Different purposes need different methods due to time scales and simulation depths
- Simulation cannot substitute tests with real systems, just decrease the number of real tests
- Simulation always needs input from real field test data for validation

# Development of control and monitoring algorithms



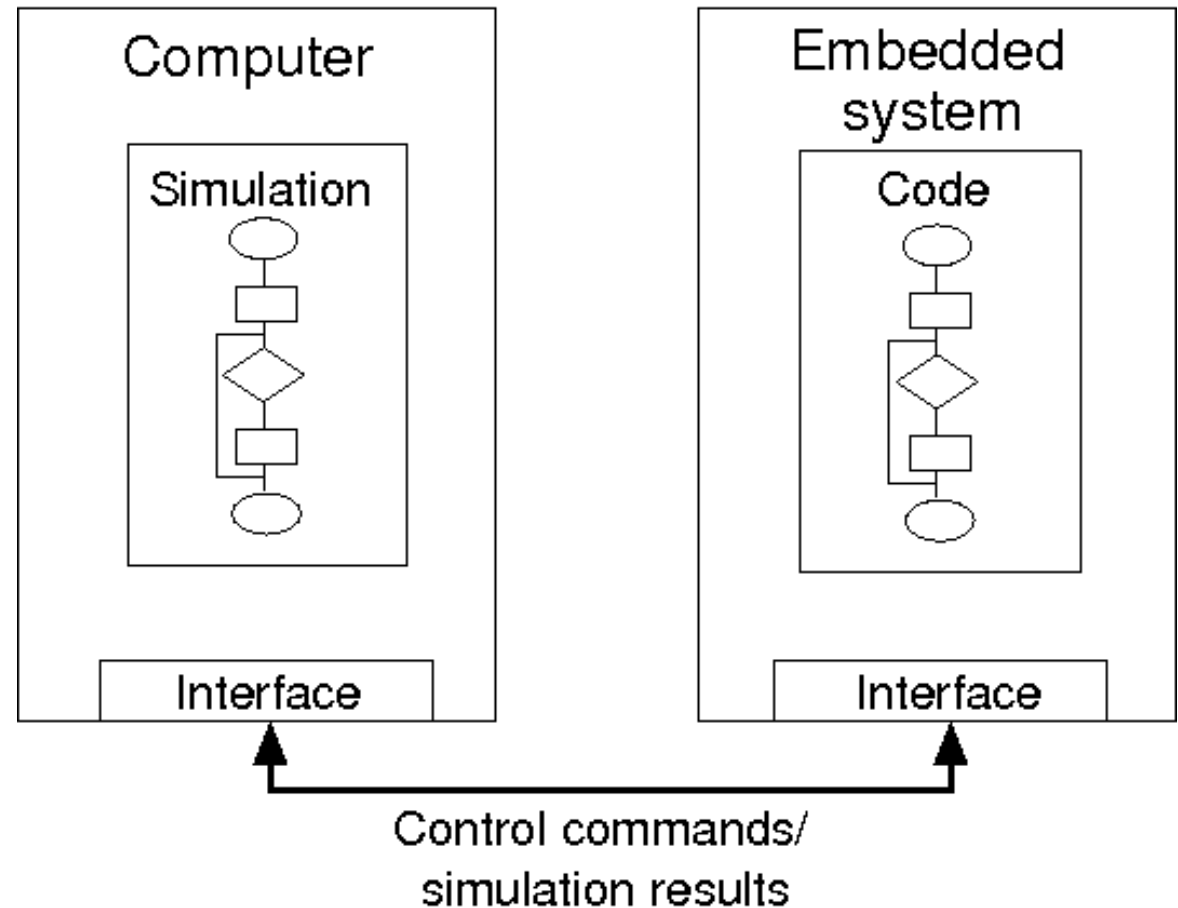
# System model for software / hardware in the loop

- System model in ANSI-C:  
Very quick calculation time, easy debugging, big modelling effort for more complex systems
- System model in simulators like Dymola/Simulink: More flexibility, quicker modeling, higher calculation times, higher costs



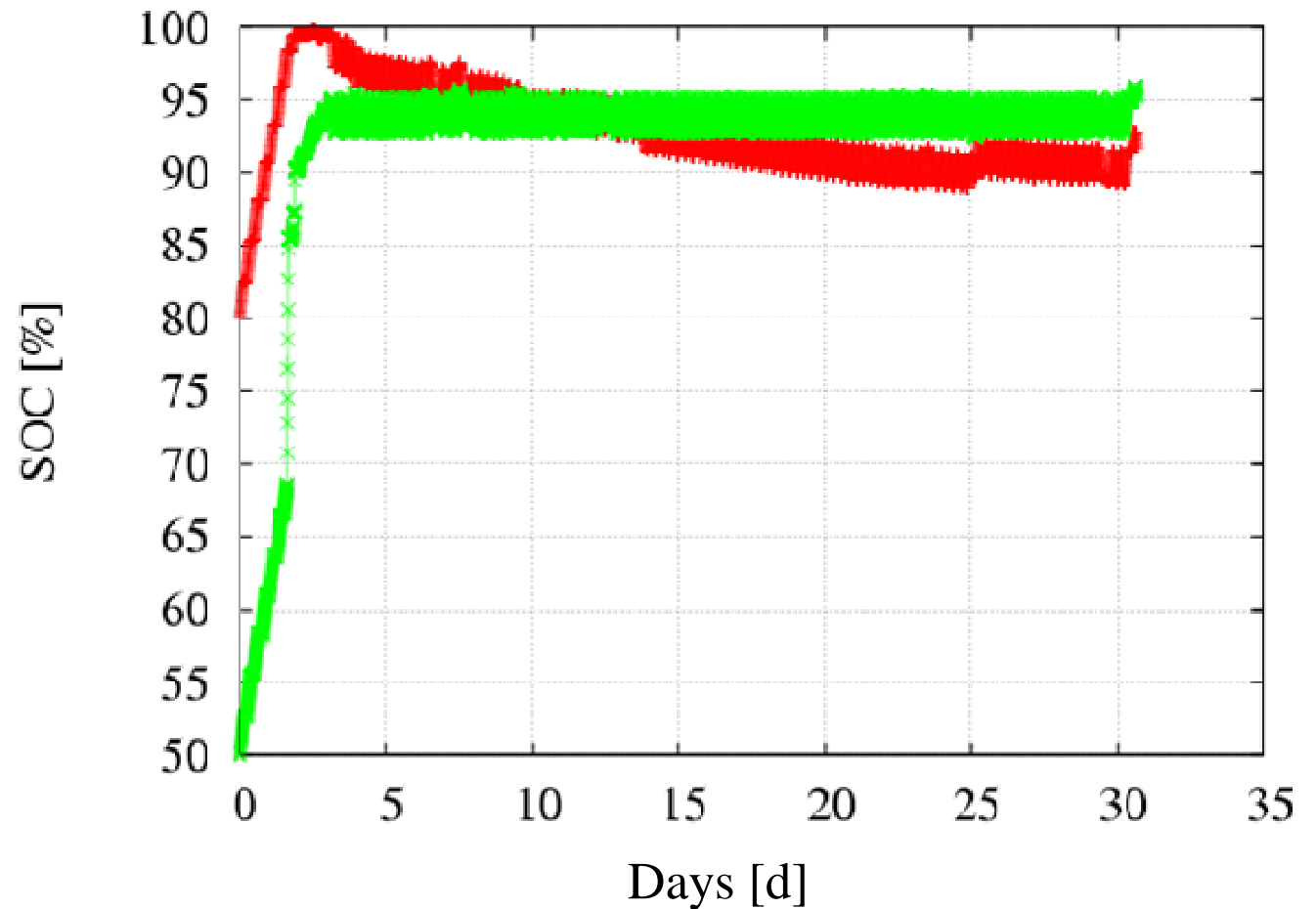
# Hardware in the loop

- Control algorithm on hardware platform
- System model on computer
- Communication via interface or analog / digital inputs / outputs
- Possibility to increase simulation speed, changing system quickly, finding bugs on hardware



# Example

- State of charge of lead acid battery
- Validation of SOC determination
- Problem because of different compilers  
→ after seven days SOC could always be just 0 or 100 %
- In simulation quick search for bug possible



Simulation (reference value) ———— SOC determination

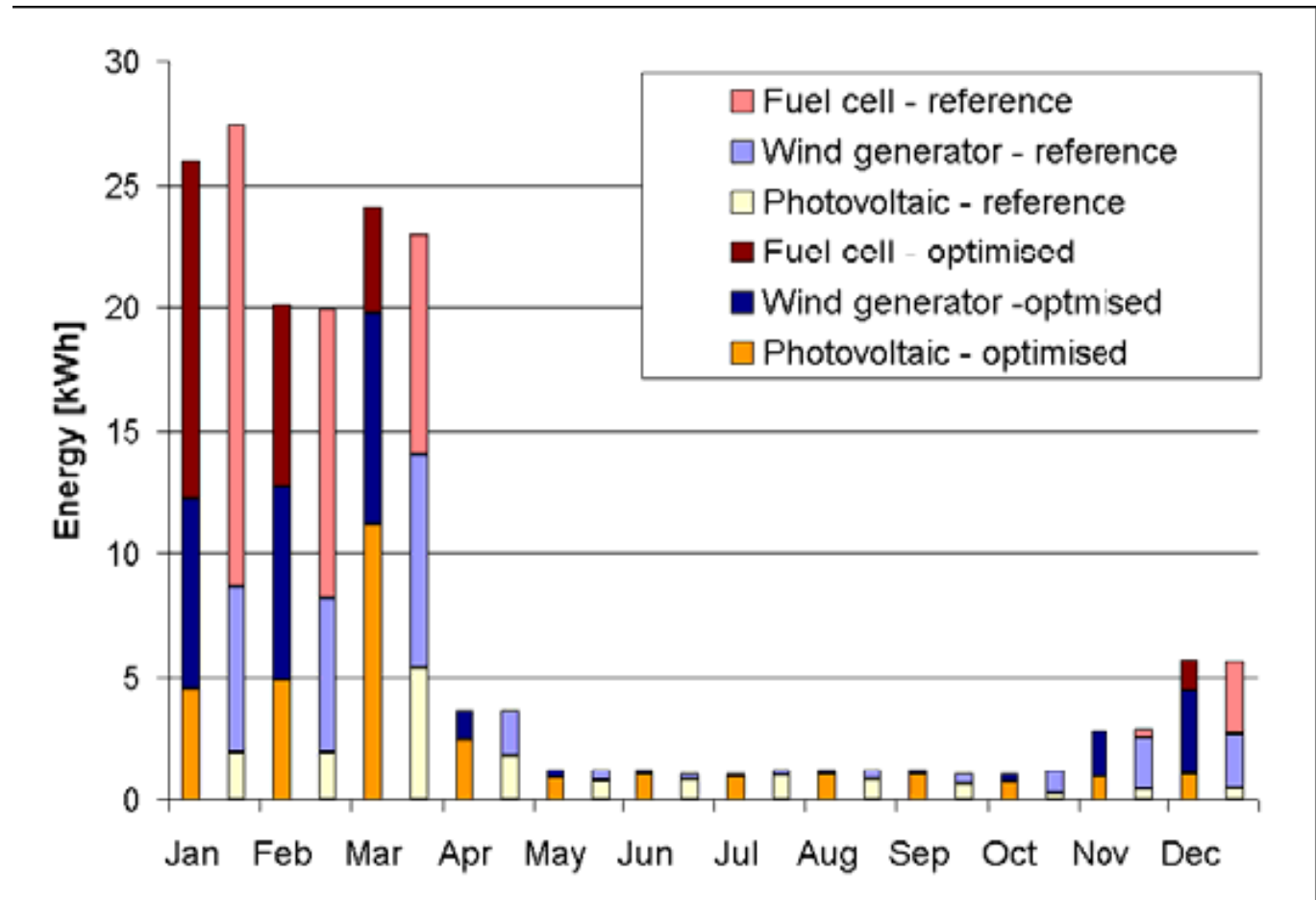
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# System design and sizing

- At least one year of simulation time necessary
- External factors:
  - data of renewable energy sources
  - load demands
  - weather
  - seasonality
  - technical, economic and other boundary conditions
- Optimisation of life cycle cost with Talco and Homer
- Sizing on technical simulation of one year with tools like Dymola or PV\*Sol

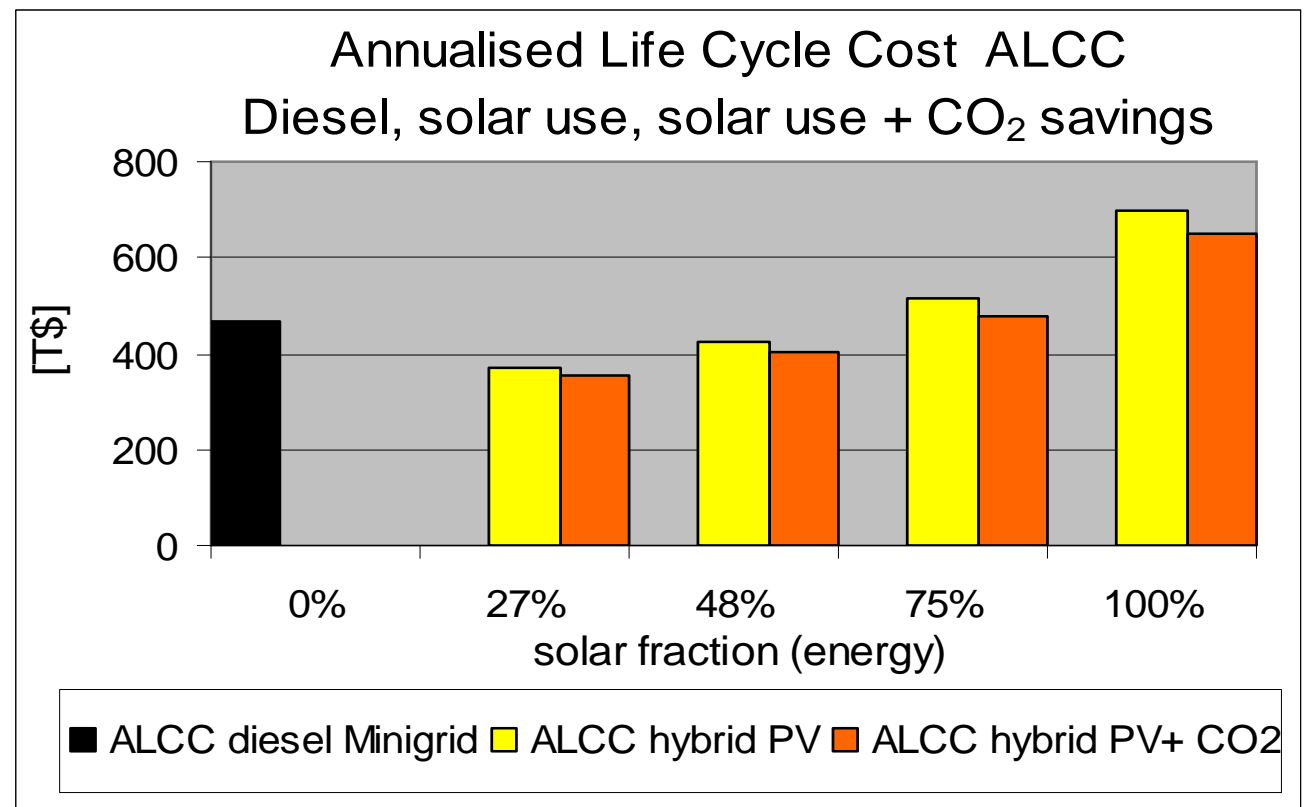
# Example for system sizing

- Minimizing energy use from fuel cell without overdimensioning of PV
- Produced energy for reference and optimised system over the year
- Dymola used for simulation



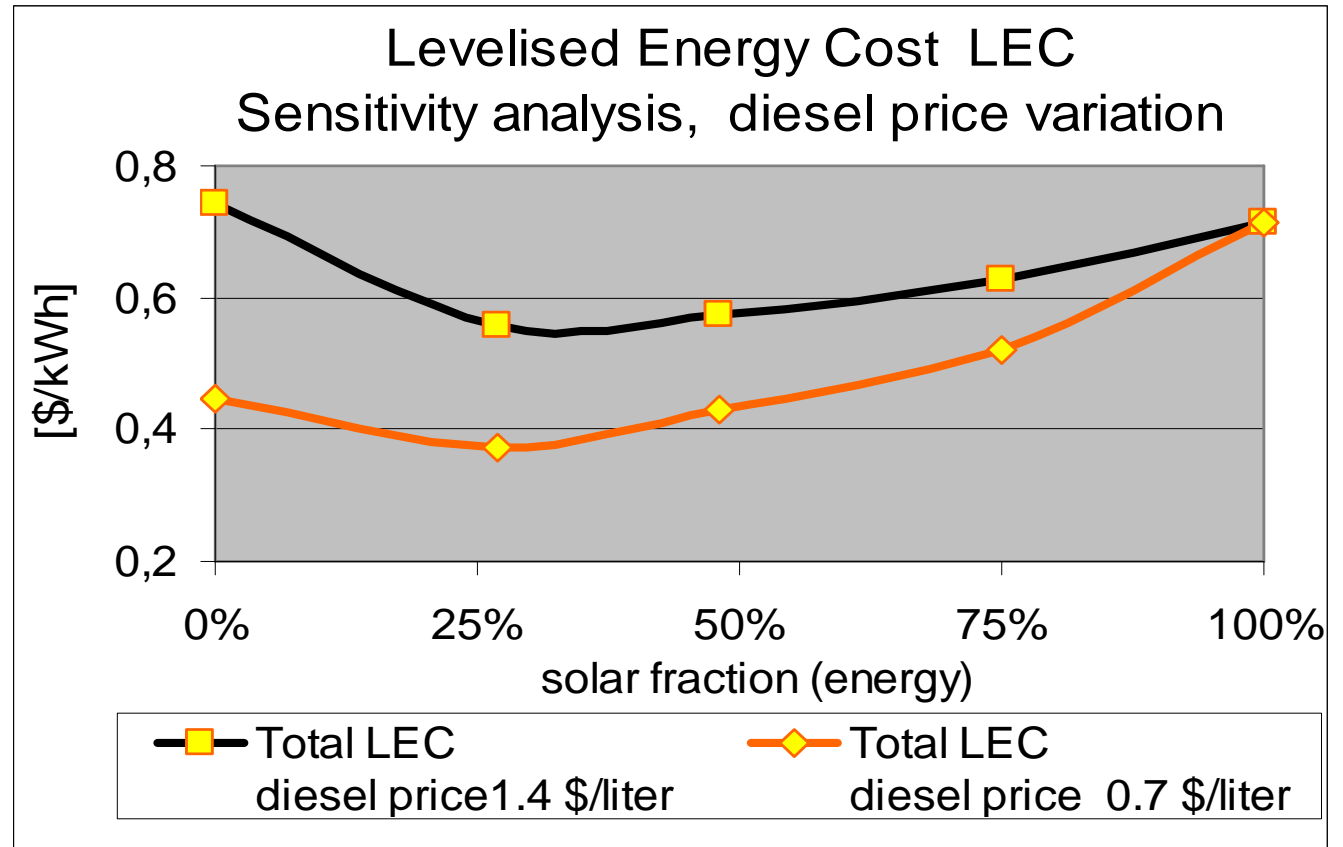
# Economic analysis of systems

- Life cycle cost covers investment and operating costs
- Includes a period of at least 20 years



# Sensitivity analysis - Increasing prices of fossil resources

- Cost optimum around 25 % solar fraction
- With rising diesel prices more PV can be included in an economically reasonable way



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# Conclusions

- Widely used in research and industry
- Simulation useful for:
  - Development of algorithms
  - System design and sizing
  - System analysis (life cycle cost, sensitivity analysis, quality of supply)
- Targets
  - Speeding up development
  - Cutting costs
  - Analysis and optimisation
- A variety of tools for different purposes

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# Thanks for your attention!

email to: [simon.schwunk@ise.fraunhofer.de](mailto:simon.schwunk@ise.fraunhofer.de)

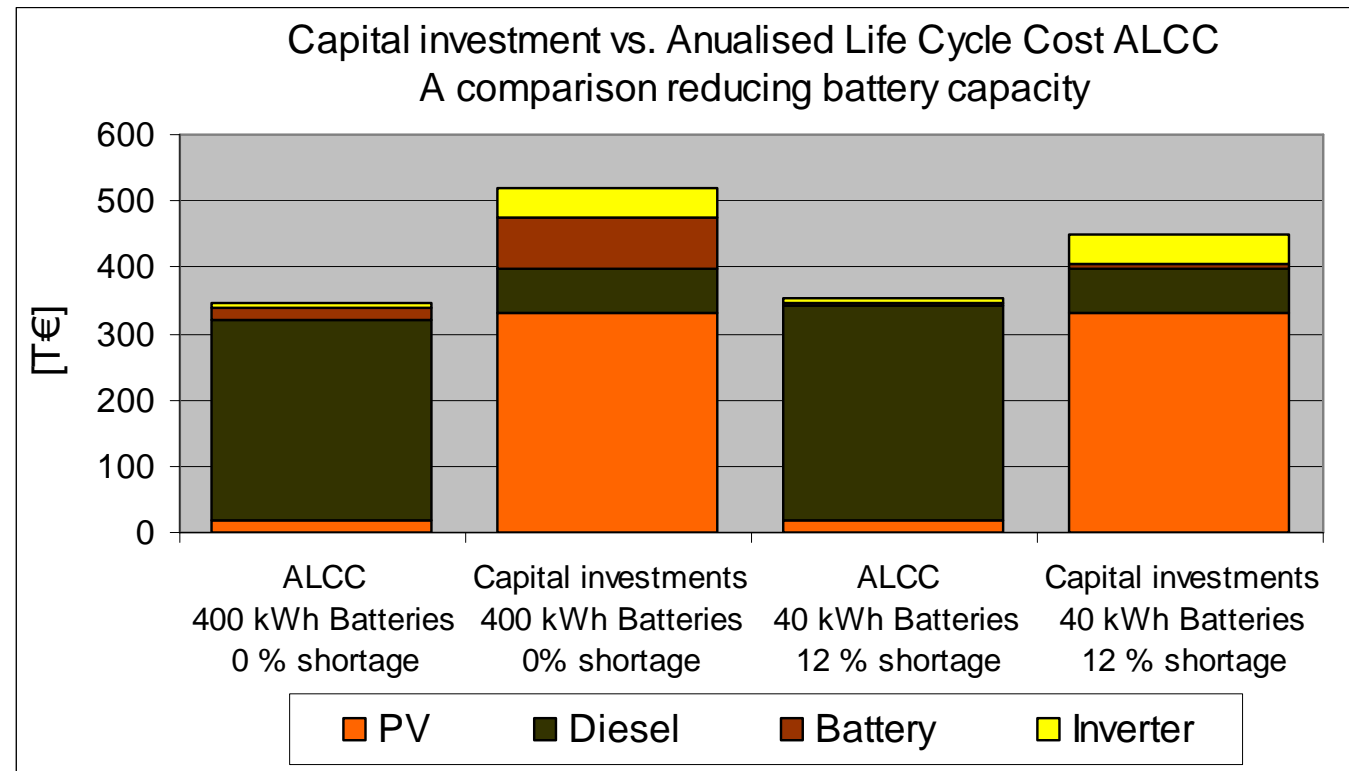
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# Analysis of systems – reference case

- 99 households, classified in four groups, a rural clinic, a fish factory
- Daily consumption 2849 kWh
- Peak power 200 kW
- Simulation in Homer, validation in Talco

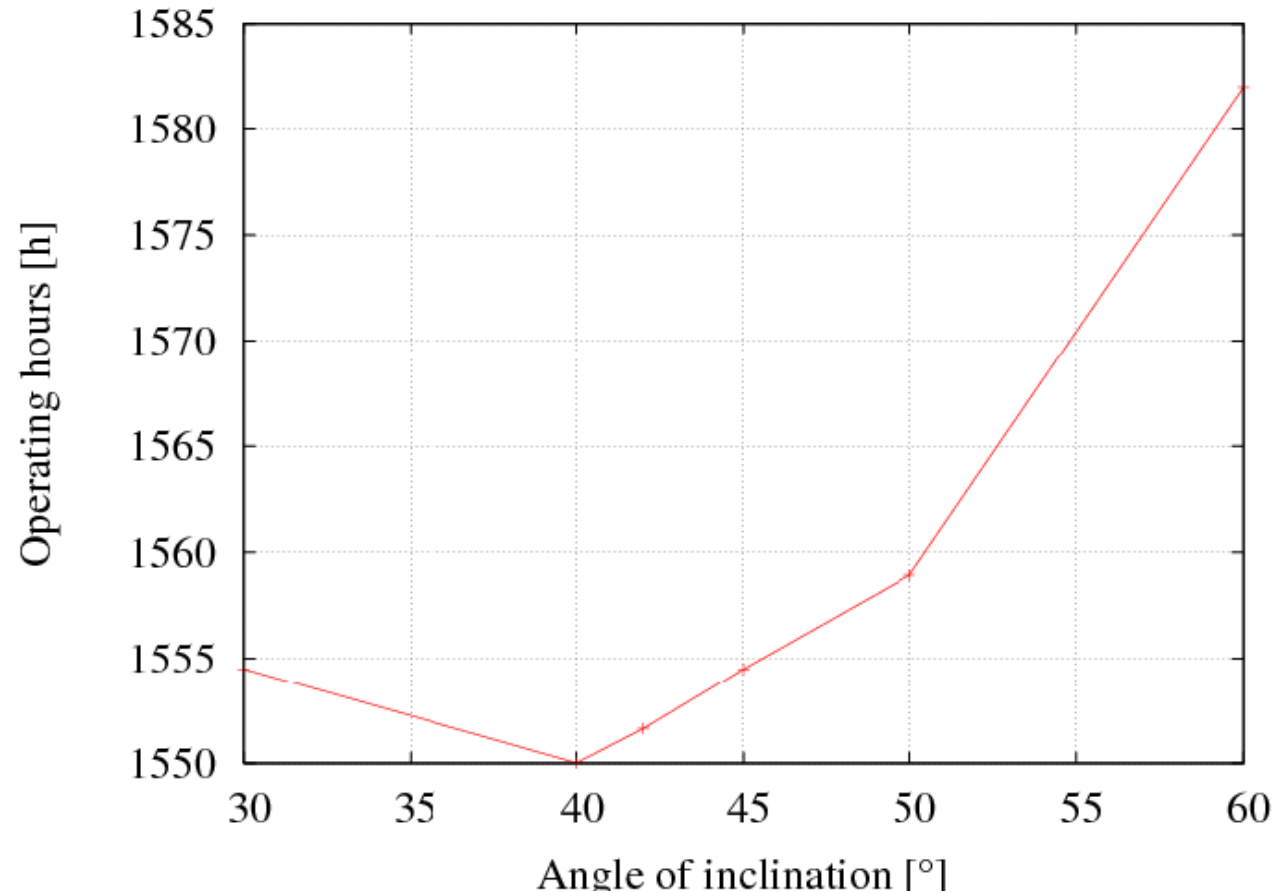
# Quality of supply -100 % secure energy supply vs. 88 %

- Comparison of life cycle cost ALCC vs. capital investment
- 6 % renewable energies
- Diesel price 0.7 €/litre



# Example for technical design

- Finding the optimum angle of inclination of PV in a hybrid PV system
- Operating hours of switchable generator in hybrid PV system
- Dymola used for simulation



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# Definition of life cycle cost

The life cycle costing methodology involves adding up all the costs including investment and operation costs of a project over the term of the evaluation, with the costs in any year being discounted back to the base period.