On-Site Generation Simulation with EnergyPlus for Commercial Buildings

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Outline

- Introduction
- The Distributed Energy Resources - Costumer Adoption Model (DER-CAM) concept and its deterministic view of the future
- DER-CAM application to a Healthcare Facility in San Francisco
- Uncertainties: The Energy Manager and its dispatch optimization
- Dispatch Optimization at a Boston Office Building
- The holistic approach with EnergyPlus - Synthesis & Conclusion

Introduction

- E+ is a building energy simulation software, capable of assessing the energy demand of buildings given their envelope design, heating ventilation, air conditioning and controls, climate, occupancy data
- Currently, limited Distributed Generation (DG) capability (e.g. absorption chiller, control strategies)
- DG investment, operation planning and dispatch optimization software (DER-CAM and Energy Manager) have been developed at Lawrence Berkeley Lab
- Currently, no link to a building energy simulation program for accurate assessment of DG designs particularly under uncertainty in future end-use loads and DG equipment availability

Introduction

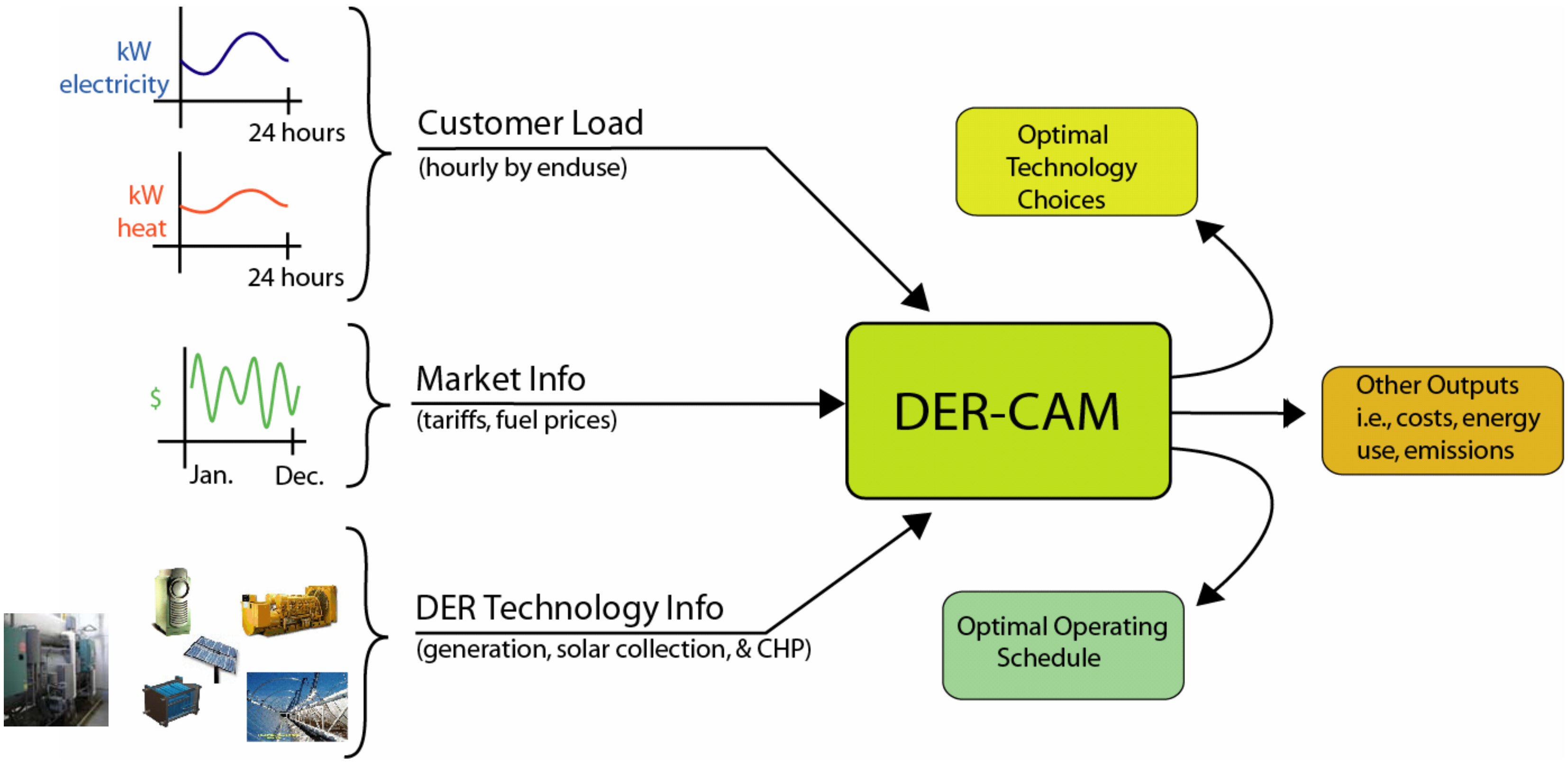
- **Extension of EnergyPlus, to enable the simulation of various DG modules** (e.g. microturbines, absorption chillers) **and associated control strategies in order to achieve more accurate and holistic analysis of DG technologies**

- Extension of EnergyPlus facilitated by SPARK, a program capable of modeling building equipment and controls as <u>individual</u> modules

DER-CAM Concept

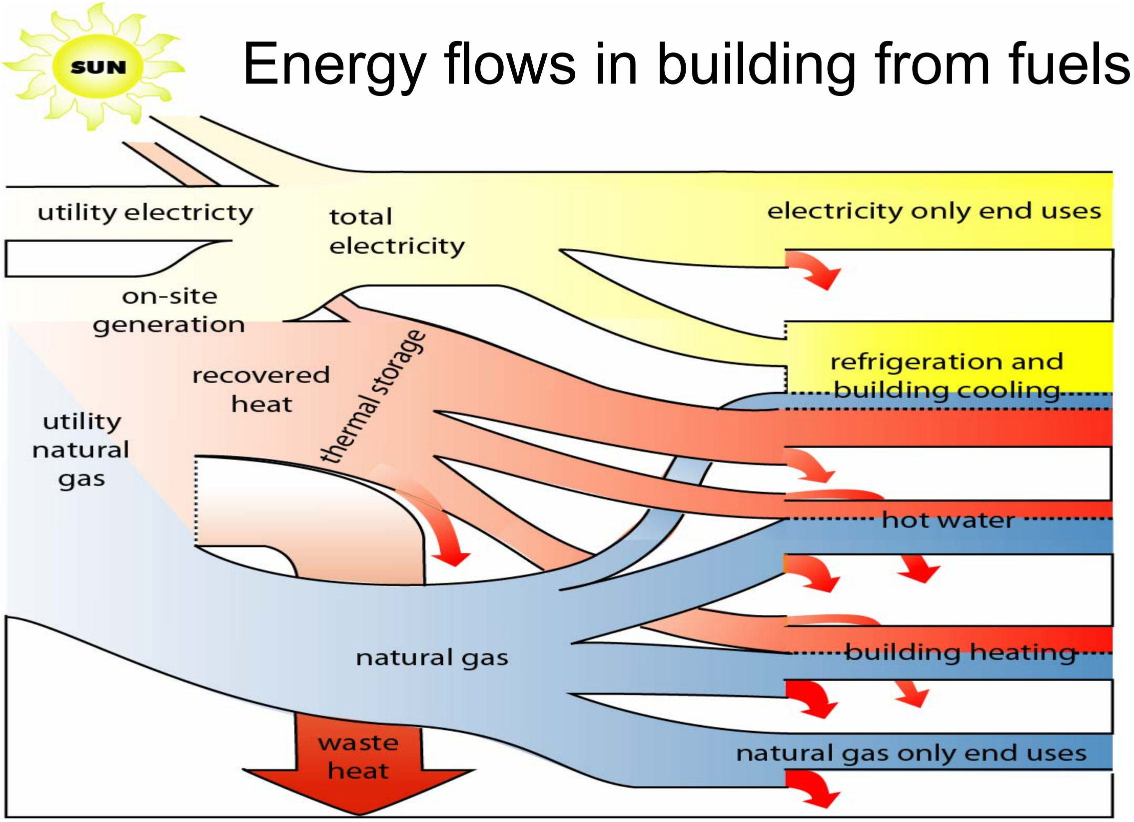
- DER-CAM is a Mixed Integer Linear Optimization Program (MILP) written and executed in the General Algebraic Modeling System (GAMS)
- The objective is to minimize annual energy costs for the modeled site, including utility electricity and natural gas costs, amortized capital costs for DG investments, and maintenance costs for installed DG equipment

DER-CAM Concept



DER-CAM Concept

Energy flows in building from fuels to end uses



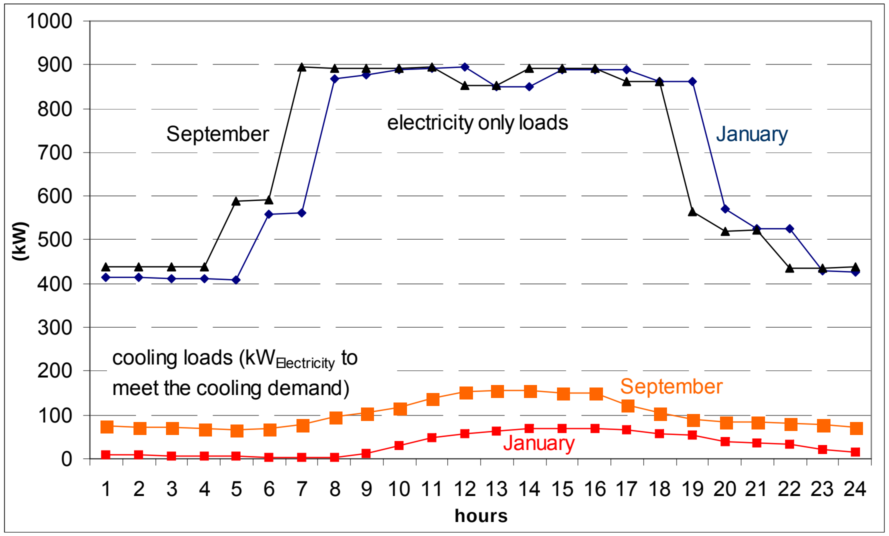
fuels

useful energy services

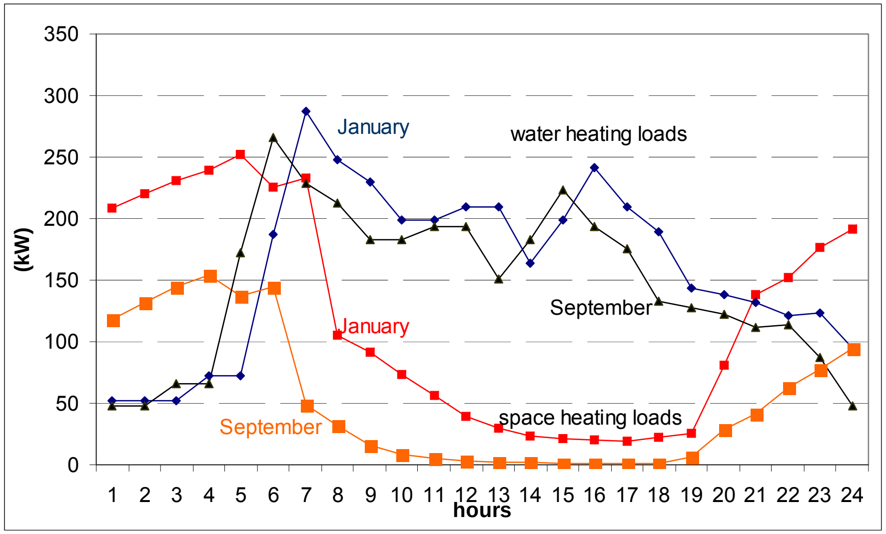
holistic, integrated, end-use focused analysis of entire building energy system

DER-CAM application – Healthcare Facility in San Francisco

Electricity only and Cooling Loads (Jan. and Sept. Weekday)



Space and Water Heating Loads (Jan. and Sept. Weekday)



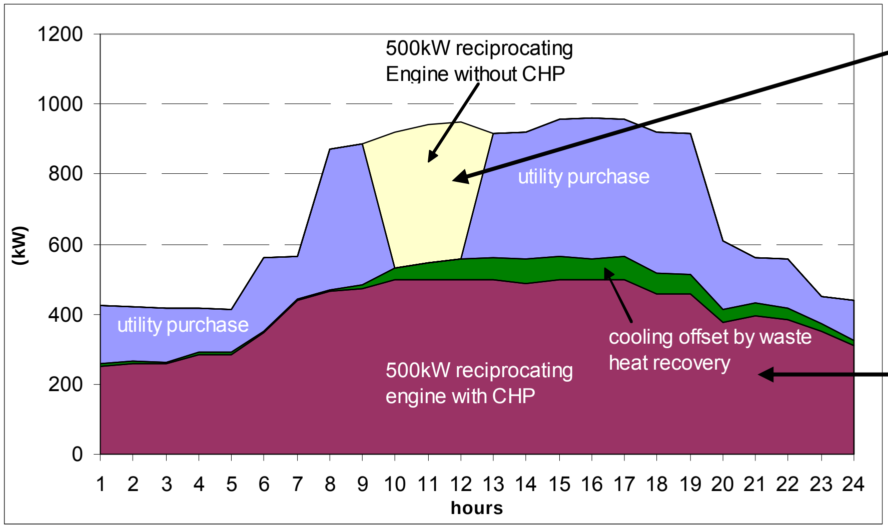
During expensive mid- and on-peak hours significant electricity and space / water heating demand, as well as cooling loads → can be met thermally by waste heat → **prime candidate for on-site generation**

DER-CAM application – Healthcare Facility in San Francisco

DER case

- Annual energy costs of $707,000 (19% reduction vs. to Do Nothing)
- Peak electricity demand of 0.85 GW (23% reduction vs. to Do Nothing)

Electricity Supply Structure with DER (Jan. Weekday)



The electricity-only unit is dispatched during the high priced peak hours of the day to reduce demand charges.

The CHP unit runs 24 hours to meet the base electric, the heating load, and to offset the electric cooling load via absorption chilling.

DER-CAM application – Healthcare Facility

- Recovered heat satisfies the entire heating demand and 74% of the annual cooling demand
- Because of the usage of CHP enabled technologies the overall system efficiency increases from 40% prior to DG investment to 48%

→ Consideration of CHP enabled DG technologies in building simulation (E+) is suggested

The Energy Manager

- DER-CAM
  - Determine optimal investment decision based on deterministic view of future
  - Chooses DER systems and estimates performance under economic optimization
  - Does not consider any relation between the change in load profiles and distributed generation (e.g. as a result of DSM)

- Energy Manager
  - Continuously determine near-optimal dispatch of an installed system in response to:
    - Non-deterministic view of the future
    - Current conditions (tariffs, outages, end-use load changes, demand-response requests, …)
  - More realistic assessment of DER system and on-site controls due to integrated, simultaneous calculation

The Energy Manager

- Optimal dispatch must take into consideration the current state of the system, historical state information, and predicted future states of the system, as well as operation constraints (e.g. curtailment frequency) and the site's energy objectives (minimize energy costs) and must be in response to *non-deterministic* site energy loads, DG equipment outages, and price signals

- Monte Carlo Approach: Generation of future scenarios for
  - Energy loads and
  - DG equipment outages

The Energy Manager

Simplified approach:

$$ExpectedCost = \frac{\sum_{scenearios} Cost(scenario)}{Number\ of\ scenarios}$$

$$with\ Cost(scenario) = \sum_{hours} f\{ElectricityPurchased(scenario,hour), ElectrictyCosts(hour), DemandCharges(scenario), NaturalGasDemandforDG(scenario,hour), NaturalGasDemandforHeat(scenario,hour), NaturalGasCosts, Dispatch(scenario,"generation-level",hour), VarCosts, FixedCosts\}$$

The optimal dispatch is contained in the solution to the minimized expected cost:

$$D(scenario,dispatch,currenthour) = argmin(ExpectedCost(dispatch))$$

Dispatch Optimization at a Boston Office Building

- Algorithm is implemented in MATLAB / DER-CAM and applied to an office building exposed to extreme high demand charges → strong potential for dispatch to mitigate demand charges
- Integrated Energy System (IES):
  - Existing CHP system with a single generator (700 kW)
  - Site can curtail a portion of its load (150 kW, 6 times/month)

	No dispatch	DG only			Curtail only			DG and Curtail		
Month		Energy cost ($)	Savings ($)	Savings (%)	Energy cost ($)	Savings ($)	Savings (%)	Energy cost ($)	Savings ($)	Savings (%)
January	$53,293	$47,727	$5,566	10.4%	$53,023	$270	0.5%	$46,177	$7,116	13.4%
February	$51,590	$46,114	$5,476	10.6%	$51,286	$304	0.6%	$44,458	$7,132	13.8%
March	$50,730	$45,595	$5,135	10.1%	$50,272	$458	0.9%	$44,258	$6,472	12.8%
April	$50,335	$45,652	$4,683	9.3%	$49,541	$794	1.6%	$44,028	$6,307	12.5%
May	$53,566	$49,289	$4,277	8.0%	$52,668	$898	1.7%	$47,662	$5,904	11.0%
June	$79,693	$72,381	$7,312	9.2%	$78,022	$1,671	2.1%	$69,124	$10,569	13.3%
July	$81,798	$74,611	$7,187	8.8%	$80,329	$1,469	1.8%	$71,193	$10,605	13.0%
August	$80,831	$74,031	$6,800	8.4%	$79,162	$1,669	2.1%	$70,989	$9,842	12.2%
September	$74,539	$68,979	$5,560	7.5%	$72,874	$1,665	2.2%	$65,624	$8,915	12.0%
October	$50,875	$48,986	$1,889	3.7%	$50,181	$694	1.4%	$47,424	$3,451	6.8%
November	$53,323	$50,827	$2,496	4.7%	$52,718	$605	1.1%	$49,503	$3,820	7.2%
December	$57,461	$56,273	$1,188	2.1%	$56,963	$498	0.9%	$54,607	$2,854	5.0%
annual	$738,034	$680,465	$57,569	7.8%	$727,039	$10,995	1.5%	$655,047	$82,987	11.2%

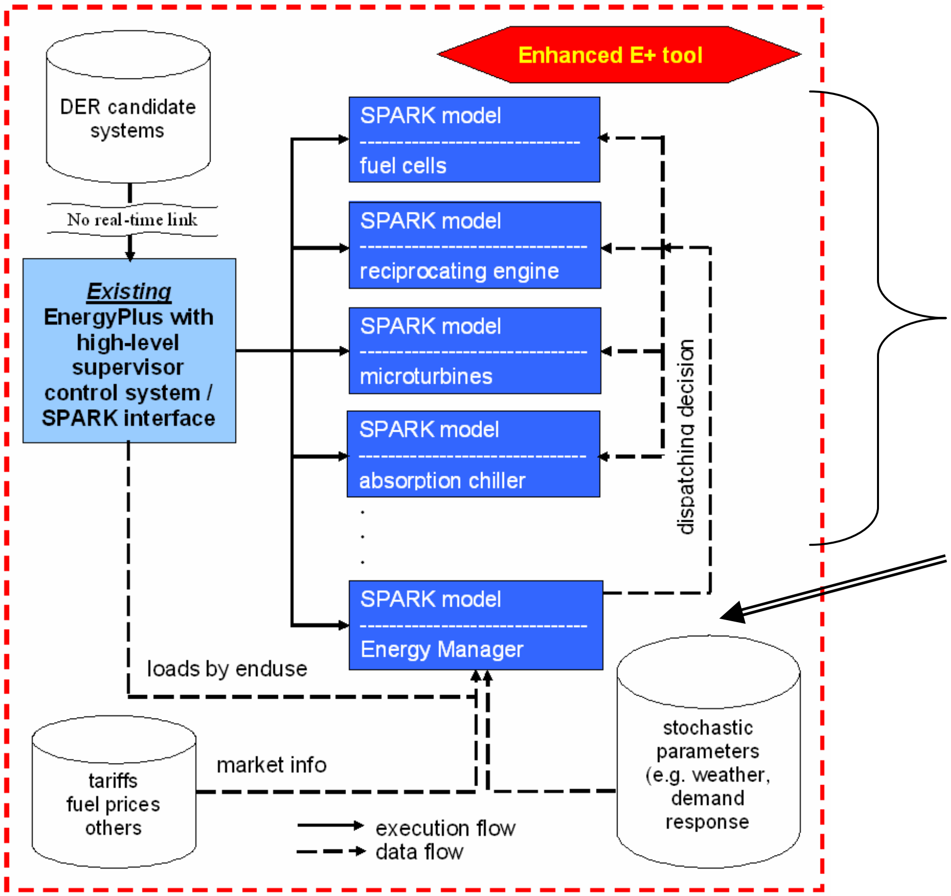
→ Benefit from DG and Curtailment is > than the sum of the single values

The holistic approach with EnergyPlus - Synthesis

- DER-CAM can provide a profound suggestion about the *optimal* DG equipment for a certain building and a deterministic view of the future
- Energy Manager: determines the optimal “real-time” dispatch of DG and curtailment options under the uncertainties mentioned above

→ Incorporation of DG enabled technologies and Energy Manager modules (strategies) into E+ to be able to simulate synergies between DG and DSM for a certain building under uncertainties

DER enabled E+ tool - Concept



Three major parts:

- Implantation of CHP enabled DER technologies (e.g. fuel cells, reciprocating engines, absorption chillers)
- Implantation of Energy Manager Algorithm (strategies) to simulate stochastic influences
- Additional economic module to estimate the energy costs

Conclusion

- CHP enabled DG technologies increase the overall system efficiency and should be considered in the building simulation
- DER-CAM is used to suggest site specific candidate DG systems
- Any DG system modelled in E+ requires a controller
- Associate controller strategies can be found with the Energy Manager and incorporated into E+
- Modular nature of modelling in SPARK → option to experiment with various control strategies
- Coupling DG system design and dispatch with curtailment and/or rescheduling → benefits greater than either of the two in isolation