ORNL – LCCP: An extensible Framework for Life Cycle Climate Performance based Design of Energy Systems

Vikrant Aute (vikrant@umd.edu)

Omar Abdelaziz (abdelazizoa@ornl.gov)

OAK RIDGE NATIONAL LABORATORY

Managed by UT-Battelle for the Department of Energy

Contents

- Background
- Project Objectives
- ORNL LCCP Framework
- Demo

Emissions Due to HVAC&R

- Emissions occur throughout lifetime
  - Leakages, service & disposal
  - Operation
  - Manufacturing & transport
- Mitigation
  - Low/No GWP alternatives
  - Efficient recovery/reuse
  - Efficient systems
  - **Systems approach towards design**

CEEE

Life Cycle Climate Performance

- Total CO2 equivalent global warming impact over total lifetime of the system
- Comprised of
  - Direct emissions: refrigerant released
  - Indirect emissions
    - Energy consumption over lifetime and recycling
    - Power input during operation, transport, processing
    - Manufacturing of systems/components, recycling
- Units: kg CO2 /kg OR CO2e

CEEE

LCCP History

- ## ORNL
  - Life cycle analysis for alternative refrigerants
  - Total Equivalent Warming Impact (TEWI)
- ## Papasavva (1997)
  - Expanded TEWI to Life Cycle Warming Impact (LCWI)
- ## Andersen (1999)
  - Montreal Protocol, Technology & Economic Assessment Panel
  - Coined: Life Cycle Climate Performance (LCCP)

CEEE

LCCP Software Efforts

- GREEN-MAC LCCP (2004)
  - Automotive
  - Peer reviewed, contribution from 50 experts,
  - http://www.epa.gov/cppd/mac/
- AHRTI (2011)
  - October 2011, AHRTI Report No. 09003-01
  - Residential heat pumps
- ORNL – LCCP (2012)
  - Project at CEEE/UMD funded by DOE/ORNL

CEEE

Future Energy Systems

- Engineered for efficiency, performance, cost,…, **LCCP**,…

- LCCP needs to be one of the design metric

- Should be one of the objectives or constraints during design optimization

CEEE

Challenges

- Standardized LCCP calculation
- Bring diverse set of analysis tools onto a single platform – without exposing any IP
  - Can serve as a platform or component of a bigger platform
- System (refrigeration vs. A/c) independent
- Transparent calculations, peer-reviewed
- Input uncertainty
- Standardized outputs

CEEE

ORNL LCCP Project

- Open Source LCCP Evaluation & Design tool

- Funded by Oak Ridge National Laboratory (ORNL) & CRADA (Honeywell)

CEEE

Project Team

- Oak Ridge National Labs (ORNL)
  - Omar Abdelaziz (abdelazizoa@ornl.gov)
  - Ed Vineyard
  - Brian Fricke (frickeba@ornl.gov)
- University of Maryland (UMD)
  - Vikrant Aute (vikrant@umd.edu)
  - Reinhard Radermacher
  - Jyothi Vinjumur
  - Mohamed Beshr

CEEE

ORNL LCCP Objectives

- **<u>Design Tool</u>**
- Build on existing methodologies
- Extensible framework for LCCP design
  - Can be coupled with existing system/load calculations tools
- Wide range of applications
  - Supermarket refrigeration, heat pumps,…
- Desktop and Web/Cloud based interfaces
- Open Source

CEEE

LCCP

Direct Emissions

- Regular emissions
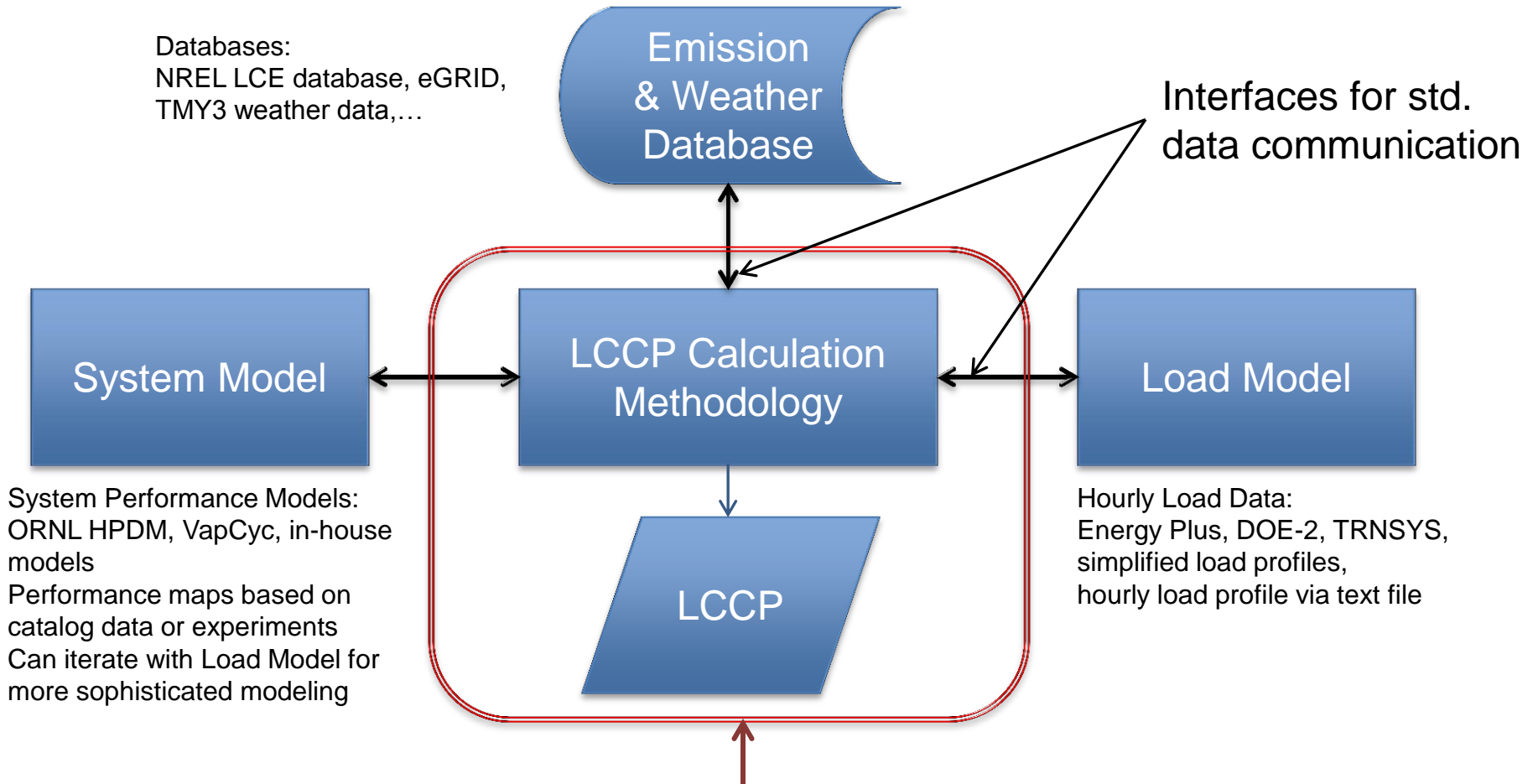- Irregular emissions
- Service emissions
- End-of-life emission
- Leakage during production & transport

Indirect Emissions

- Energy consumption of the system
- Energy to make system/components
- Energy to produce refrigerant
- Energy to transport
- Energy for end-of-life, recycling/recovery of system and refrigerant

* Also included are place-holders for user-defined emissions

CEEE

ORNL LCCP Framework

Databases:
NREL LCE database, eGRID,
TMY3 weather data,…

Emission & Weather Database

Interfaces for std. data communication

System Model

LCCP Calculation Methodology

Load Model

LCCP

System Performance Models:
ORNL HPDM, VapCyc, in-house
models
Performance maps based on
catalog data or experiments
Can iterate with Load Model for
more sophisticated modeling

Hourly Load Data:
Energy Plus, DOE-2, TRNSYS,
simplified load profiles,
hourly load profile via text file

Components will be developed as "Open Source".
Other components can be open-source or proprietary

CEEE

LCCP Inputs

- ## System
  - Charge, lifetime, annual leak rate, accident & service leak rates, service intervals, power consumption

- ## Refrigerant
  - GWP, energy and leakage during [manufacturing, transport, and recycling]

- ## Components
  - Mass, energy required for [manufacturing, transport, recycling]

- ## Application
  - Weather, power-plant emissions, renewable factor

* Also included are place-holders for user-defined inputs; Energy ≡ CO_2e.

Role of System Simulation Tool

- Indirect emissions: 20%-80% of total

- LCCP approach involves hourly energy consumption calculations, 8760 evaluations

- Robust system simulation tool
  - For novel systems
  - Fast & flexible
  - Allow system design/optimization with LCCP as one of the criterion

CEEE

System Simulation

- Given: Ambient conditions and load profile, compute hourly power consumption
- System simulation invoked via "exe" file
- I/O through text files
- Accounts for multiple cycles in a system
- Allows for parametric studies
  - Change system and component level input

CEEE

System Simulation - VapCyc

- Support for VapCyc
  - Tool for analyzing VCC
  - Support for user-defined refrigerant mixtures and detailed component design
- Implementation
  - Dynamic curve fitting approach for capacity and power consumption as a function of ambient conditions
  - Significant computational savings

CEEE

Emission/Weather Data

- TMY3 Database
- 16 pre-defined cities
- User can add additional cities
  - Weather data file
  - Emissions data file

CEEE

Load Integration

- Hourly load profile files (txt)
- Integration with EnergyPlus
- Option to by-pass simulation tool and read power consumption from file

CEEE

ORNL LCCP Web App

- http://lccp.umd.edu/ornllccp/
- Simplified application for evaluating LCCP of supermarket refrigeration systems
- Commonly used medium and low temperature applications
- Pre-defined cities and load profile(s)

CEEE

Challenges

- System comparison based on total emissions
  - Impact of individual contributions
- Where to get input data?
  - Non-profit, industry collaboration

Status

- Public BETA available in November 2012
- http://lccp.umd.edu/ornllccp
  - Web version, Desktop version download
  - Support forums

CEEE

Future Directions -

- Refine calculations
  - Request for comments
  - Multiyear charge effects
- Out of box support for other systems
  - Residential heat pumps
  - Secondary loop systems
- Simplified input
  - Work with user input performance data
- Uncertainty/Sensitivity Analysis

CEEE

ORNL LCCP – Web Version Demo

- http://lccp.umd.edu/ornllccp

CEEE

LCCP Desktop Version Demo

CEEE

Thank You