Teaching SAM to Engineering Students

Professor Frank Kreith
Charles Tse
University of Colorado in Boulder

Biography

Frank Kreith, Doc Sci., P.E.
Professor of Engineering (Emeritus)
University of Colorado

Dr. Frank Kreith has taught at the University of California, Lehigh University, and the University of Colorado, where he is now Professor Emeritus of Engineering. From 1988 to 2001 he was the American Society of Mechanical Engineers International (ASME) Legislative Fellow for Energy and Environment at the National Conference of State Legislatures (NCSL) where he provided assistance on energy, transportation and environmental protection to legislators in all fifty state governments. Prior to joining NCSL in 1988, Dr. Kreith was the Chief of Thermal Research at the Solar Energy Research Institute (SERI), currently the National Renewable Energy Laboratory. During his tenure at SERI, he participated in the Presidential Domestic Energy Review, served as an energy advisor to the Governor of Colorado, and was the editor of the ASME Journal of Solar Energy Engineering. He is the author of over a hundred peer-reviewed articles and of textbooks on heat transfer, solar energy and transportation. He is the recipient of the Charles Greeley Abbot Award from American Solar Energy Society and the Max Jakob Award from ASME-AIChE. In 1992, he received the Ralph Coats Roe Medal from ASME for providing technical information to legislators about energy conservation and environmental protection, and in 1997 the Washington Award for “unselfish and preeminent service in advancing human progress.” In 1998, Dr. Kreith was awarded the ASME medal for research, publications and public service and in 2004 he was named ASME Honorary Member. In 2005 the ASME established the Frank Kreith Energy Award in recognition of Dr. Kreith’s contribution to heat transfer and renewable energy. He now teaches an Honors course on Sustainable Energy at the University of Colorado and published a text on this topic entitled *Principles of Sustainable Energy* in 2010 and is now preparing the second edition.

Biography

CHARLES TSE

2008 — Graduated from Grandview High School — GPA 3.9/4.5

Awards: AP Scholar with Distinction
Distinguished Scholar
National Honors Society Award
Spanish Honors Society Officer Award

Achievements: Varsity Tennis Team

Experience: Volunteer Student Tutor

2008 – 2012 — University of Colorado at Boulder

Graduated 2012, B.S. in Mechanical Engineering — GPA 3.51/4.0

Awards: Dean's List: Fall '12, Spring '12
Schuman Merit Scholarship

Achievements: CU Club Tennis Team

Experience: Tutor for Academic Support Assistance Program (ASAP)

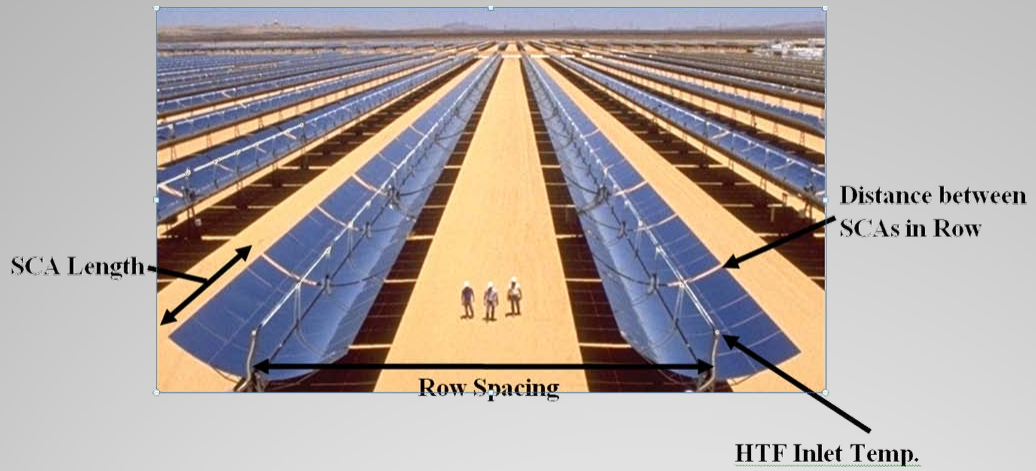
2012 – Current — Graduate Student in Mechanical Engineering, Design track

Experience: Editorial Assistant for Professor Kreith's 2nd Ed. *Principles of Sustainable Energy*
R&D for System Advisor Model in College Education
Tutor for ASAP

Background of Students

- Thermodynamics
- Heat Transfer
- Basic Economics
- Excel spreadsheets
- Learning solar/wind technology

- Relate technology design to SAM data input
  - Needs schematic



  - Define new variables (e.g. solar multiple)
- Give easy access to definitions
  - Allow student to click on the word and a bubble pops up with definition
- SAM-text interface
  - Use simple basic examples
  - Calculate by hand and compare with SAM

Improving Student Experience

Level of Expertise

- Technology input is empirical
  - Selected from limited library instead of basic design
  - Does not size system from energy needs
- Economics highly detailed
  - More detail = more uncertainty
  - Too much emphasis is placed on minor economic issues
- Number of significant figures not compatible with uncertainty
- Expected accuracy of real world estimates is ± 15%

Proposed Additions to SAM

- Student version would be helpful
  - Many variables in SAM are too detailed and not important within accuracy limitations
    - Incident Angle Mod Coeff 1, 2, and 3 of SCA
    - Piping Heat Loss Coeff 1, 2, and 3 of HTF
    - Cost variables of any system
- Energy Return of Energy Invested

$$EROI = \frac{energy\ delivered}{energy\ invested}$$

  - Eliminates uncertainty of future economics and politics (e.g. tax rebates)
  - Much simpler to use than economics

1. Useful energy output from SAM (E_{out})
2. Financial input for system (mostly provided by SAM)
3. Conversion of dollar input to energy input with existing tables of $/Btu or $/kWh
4. Sum energy input by simple addition (E_{in})
5. $$EROI = \frac{E_{in}}{E_{out}}$$

Steps in EROI

BUFFALO RIDGE WIND FARM (PHASE I)

Energy investment to construct and maintain a 25 MW wind farm

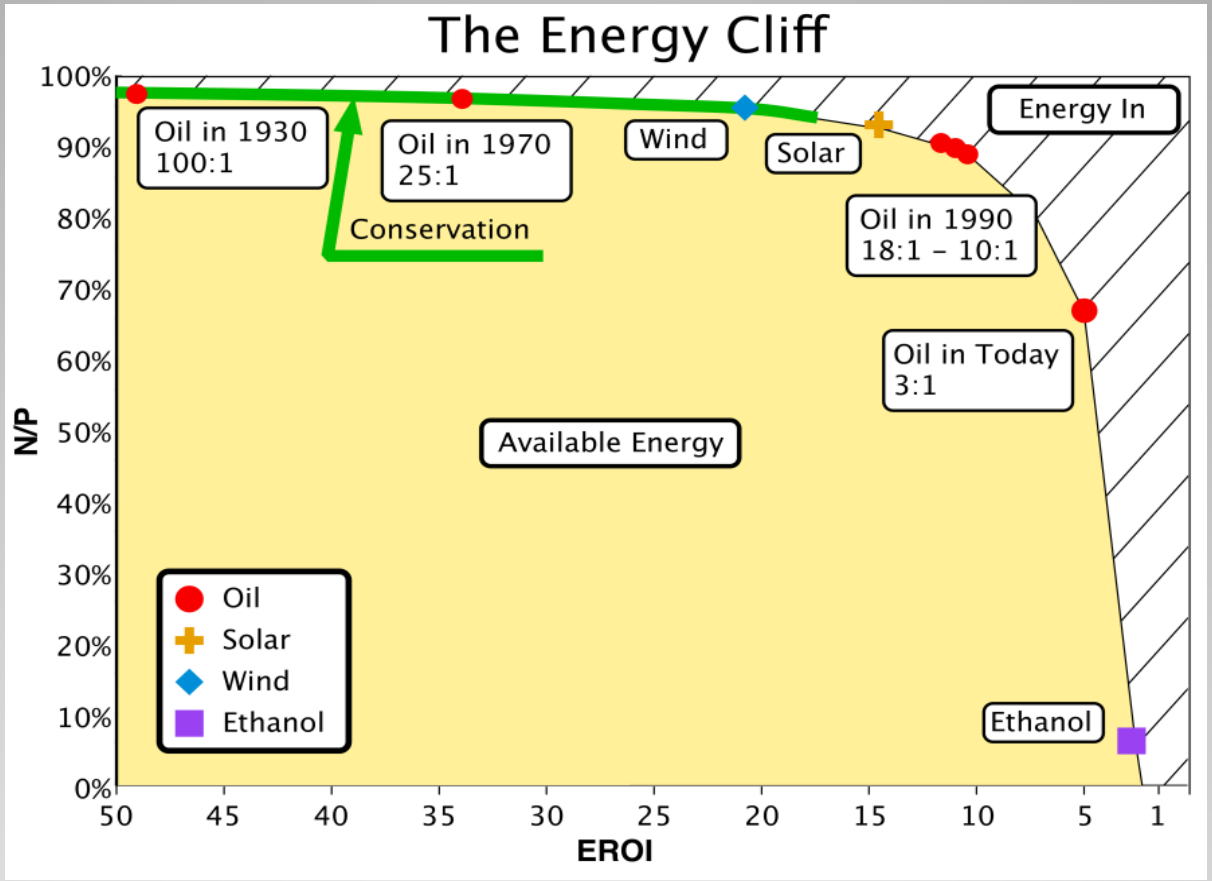
	INITIAL ENERGY INVESTMENT (GJ)		ANNUAL ENERGY INVESTMENT (GJ/GWY)
Blades	6,363		4.76
Nacelles	17,499		13.08
Inverter	12,385		9.26
Wiring	696		0.52
Tower	49,431		36.94
Foundation	13,694		10.23
Materials total	100,068		74.79
Transportation to site	15,094		11
Construction	15,305		11
Operation/Maintenance	74,625		56
Decommissioning	7,652		6
TOTAL ENERGY INVESTMENT	212,744 GJ	plus	158.79 GJ/GWY

ENERGY RETURN FROM 25 MW WIND FARM (ESTIMATED)

Rated power output	25 MW
Capacity factor	25.6 percent (measured from 1994 to 1998)
Hours of operation	~153,000 (since 1994)
Conversion factor	3,600 J/Wh
TOTAL ENERGY RETURN	~3,500,000 GJ

ENERGY RETURN ON ENERGY INVESTMENT

Net energy	3,500,000 GJ
Energy investment	212,744 GJ
EROI since 1994	16.5
EROI over 25-year operation	23.5



Available Energy vs. EROI

Conclusions

- Make SAM more student friendly
  - Include schematic
  - Easier to access definitions to inputs
  - SAM-text interface
- Empirical technology isn't effective
- Level of detail is too much
  - Economics and significant figures
- Consider adding:
  - Student version
  - EROI calculations

Questions?