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Cook-STePS

Expanding lab tests information by means of thermodynamic simulations



Why do we need simulations?



What is Cook-STePS?

- It's a free and open-source tool based on Excel/VBA and provided with a GUI
- Developed by Politecnico di Milano Department of Energy, UNESCO Chair in Energy for Sustainable Development
- Simulates thermal performances of stoves in selected conditions by means of a heat and mass transfer model
- Incorporates stochastic functions to simulate
 variable and uncertain boundary conditions
- Aims helping protocols comparability and at bridging the lab-field gap



The concept behind Cook-STePS

Lombardi, L. Colombo, E. Colombo, Design and validation of a Cooking Stoves Thermal Performance Simulator (Cook-STePS) to simulate water heating procedures in selected conditions, Energy. 141 (2017) 1384–1392. <u>https://doi.org/10.1016/j.energy.2017.11.045</u>



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Losses from water surface

$$\begin{split} \dot{Q}_{rad,w} &= \varepsilon_w \sigma A (T_w^4 - T_\infty^4) \quad [W] \\ \dot{Q}_{conv,w} &= h A (T_w - T_\infty) \quad [W] \\ h &= \frac{\overline{Nu_L} \cdot k_{air}}{L_c} \quad [W/m^2 K], \quad \overline{Nu_L} = 0,54 \cdot Ra_L^{1/4} \\ \text{Losses from pot sides} \\ \dot{Q}_{rad,pot} &= \varepsilon_{mat} \sigma A_{side} (T_w^4 - T_\infty^4) \quad [W] \\ \dot{Q}_{conv,pot} &= h_{side} A_{side} (T_{pot} - T_\infty) \quad [W] \\ \overline{Nu_L} &= 0,64 + \frac{0,67 Ra_L^{1/4}}{[1 + (0,492/\operatorname{Pr})^{9/16}]^{4/9}} \\ \dot{Q}_{useful} - \sum_i \dot{Q}_{loss,i} = \frac{\partial U}{\partial t} + \dot{m}_{eva} \Delta h_{eva} \end{split}$$

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New features (v. 2.0)

- Enhanched stochasticity (fluctuating power, variable conditions, stochastic result curves)
- Enhanched Virtual Field representation (simulates pot shapes, material, fuel type, wood species, moisture content, altitude, burning sequence)
- Pre-defined Virtual Lab Protocols: WBT, EPTP (HTP work-in-progress)
- Refined and enhanced GUI

Cook-STePS v.2.0 User Interface

Introduction

Cook-STePS

Cooking Stoves Thermal Performance Simulator v.2.0

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Welcome to the Cooking Stoves Thermal Performance Simulator - Cook-STePS. Please click " HELP" if you are using the tool for the first time or if any error occurs.

In order to properly use this software, it is required to know the average Useful Power range that the selected device can deliver to the bottom of the pot. If this is the case, please dick "YES".

If you don't know the average Useful Power range of your stove, you can rely on Cook-STEPS' Power Calculator function, which activates by clicking "NO". The Power Calculator allows for an estimate of the average Useful Power based on experimental data in controlled (lab) conditions. We suggest to perform at least 5 laboratory test replicates and to follow the Cook-STEPS testing protocol (see User Manual), recording: - the time intervals required by a selected amount of water to increase its temperature by ranges of 10°C;

- the LHV of the fuel;

- the overall mass of fuel burnt;
- the average ambient conditions.





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Cook-STePS v.2.0 Power Calculator

Fixed Parameters and Number of Experiments					
Pot Height: H	11.5	[cm]			
Pot Diameter: D	19,5	[cm]			
Pot Weight: m_pot	309	[g]			
Mass of Water: m_water	2500	[g]			
Water Initial Temperature: Tw_in	30 🔻	[°C]			
Water Final Temperature: Tw_fin	80 -	[°C]			
LID	NO 💌				
Fuel V	/ood 👻				
Wood Douglas fir 💌					
How many experimental tests have you performed?					
Back to Main Menu		ок			

Power Calculator Tool				×
Temperature Range [°C]		Time Inte [hh.mm.:	erval ss]	
N/A		00.00	.00	
30-40				
40-50				
50-60				_
60-70				_
70-80				_
N/A		00.00	.00	
Fuel Moisture Content			[%]	
Average burning rate			[g/min]	
Ambient Temperature			[°C]	
Relative Humidity			[%]	
	ОК			

Cook-STePS v.2.0 Virtual Field

Virtual Field Simulation - Data Input

Cooking Stoves Thermal Performance Sinulator v.2.0 Cooking Stoves Thermal Performance Sinulator v.2.0 Caynight (C) 2018 Politeorico di Milano, UNESCO Chair in Energy for Sustainable Development research group GNU GPU v.3.License Laboratory parameters Useful Power range (P min - P max) 900 1200 [M] Firepower (FP) 5600 WJ Fuel Wood Douglas fir T <l< th=""><th></th><th>-</th><th></th><th></th><th></th><th></th></l<>		-				
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Water initial mass (m_w,in) 4500 [g] LID YES Black Pot Image: Content range (MC min - MC max) Kind of Fuel Wood Acacia Moisture Content range (MC min - MC max) 7 15 Number of Iterations 30	Water Final Temperatu	re (T_fin)		99	[°C]	
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Number of Iterations 30	Moisture Content range	e (MC min - MC max)		7	15	[%]
	Number of Iterations			30		
		1		1 30		

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Virtual Field – Stochastic results single task

Virtual Field Simulation Results



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Virtual Field – Stochastic results single task

Virtual Field Simulation Results Specific Consumption • Load chart Specific Consumption 0,090 0,080 0,070 0,060 0,050 (WI//Win 0,050 0,040 0,030 0,020 0,010 0,000 20,0 40,0 30,0 50,0 60,0 70,0 80,0 90,0 100,0 T [°C] Average Results

Back to Data Input

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Virtual Field – Stochastic results multiple tasks

Complex Cycle - Results



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Cook-STePS v.2.0 Virtual Lab Protocol

WBT Simulation

Cook-STePS

Cooking Stoves Thermal Performance Simulator v.2.0

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Pot Geometry

Pot He	eight	11,5	[cm]		- Call /
Pot Di	ameter	19,5	[cm]	-	
Pot W	eight	309	[9]		C P
Pot M	aterial	Steel	-	in- The	and the second second
Ambi	ient Condition			the second second	-
Relati	ve Humidity range (RH min - RH	max)	20	35	[%]
Ambie	nt Temperature range (Tamb m	nin - Tamb max)	20	28	[°C]
Altitud	le		400	[m]	
Test	parameters		,		
Initial	Water Temperature (Tw_in)	23	[°C]		
Water	r initial mass (m_w,in)	2000	[9]		
Usefu	l Power range (P min - P max)	900	1200	[W]	
Firepo	ower (FP)	5600	[W]		
Kind o	f Fuel	Wood	•	Douglas fir	•
Moistu	ure Content in Laboratory	7	[%]		
Numb	er of Simulations	10			
	Back to Main Menu				Simulate Protocol

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Cook-STePS v.2.0 Virtual Lab Protocol

WBT Results



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Cook-STePS v.2.0 Virtual Lab Protocol

WBT Average Results



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How to download, use and contribute?

- Cook-STePS is conceived as a project in continuous development, and not as a definitive solution.
- The software will be released on GitHub with a User Manual (planned release April-May 2018)
- Everyone will be welcomed to use Cook-STePS and moreover to contribute to its further refinement and improvement, via the GitHub repository
- Follow the updates on our Researchgate page! (<u>https://www.researchgate.net/profile/Francesco_Lombardi6</u>)