Cook-STePS
Expanding lab tests information by means of thermodynamic simulations

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Why do we need simulations?

- **Lab tests** dominate the literature about stoves performance evaluation
- Very often used *beyond the scope* they were originally designed for
- Field tests are expensive and demanding

- Moreover, **many different lab protocols** are adopted worldwide
- Comparability is hard
- Even in the lab, **many replicates** are needed to ensure statistical significance
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

The concept behind Cook-STePS


\[
\sum_i \dot{Q}_{\text{loss},i} + \dot{Q}_{\text{useful}} = \dot{Q}_{\text{input}}
\]

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Losses from water surface

\[
\dot{Q}_{\text{rad},w} = \varepsilon_w \sigma A (T_w^4 - T_\infty^4) \quad [W]
\]

\[
\dot{Q}_{\text{conv},w} = h A (T_w - T_\infty) \quad [W]
\]

\[
h = \frac{\overline{Nu}_L \cdot k_{\text{air}}}{L_c} \quad [W/m^2K], \quad \overline{Nu}_L = 0,54 \cdot Ra_L^{1/4}
\]

Losses from pot sides

\[
\dot{Q}_{\text{rad},pot} = \varepsilon_{\text{mat}} \sigma A_{\text{side}} (T_w^4 - T_\infty^4) \quad [W]
\]

\[
\dot{Q}_{\text{conv},pot} = h_{\text{side}} A_{\text{side}} (T_{\text{pot}} - T_\infty) \quad [W]
\]

\[
\overline{Nu}_L = 0,64 + \frac{0,67 Ra_L^{1/4}}{[1+(0,492/Pr)^{9/16}]^{1/9}}
\]

\[
\dot{Q}_{\text{useful}} - \sum_i \dot{Q}_{\text{loss},i} = \frac{\partial U}{\partial t} + \dot{m}_{\text{eva}} \Delta h_{\text{eva}}
\]
New features (v. 2.0)

- **Enhanced stochasticity** (fluctuating power, variable conditions, stochastic result curves)

- **Enhanced 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

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 click "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.

Do you already know the useful power?

[YES] [NO] → Power Calculator

What do you want to do?

- Simulate a Standardized Protocol
- Virtual Field Simulation

Proceed with the Simulation [Help]
Cook-STePS v.2.0 Virtual Field

**Cook-STePS**
Cooking Stoves Thermal Performance Simulator v.2.0
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### Laboratory parameters
- **Useful Power range (P min - P max)**: 900 - 1200 [W]
- **Firepower (FP)**: 5600 [W]
- **Fuel**: Wood
- **Moisture Content**: 7 [%]

### Pot geometry
- **Pot Height**: 14 [cm]
- **Pot Internal Diameter**: 26 [cm]
- **Pot Mass**: 1165 [g]
- **Pot Material**: Copper

### Virtual Field ambient conditions
- **Relative Humidity range (RH min - RH max)**: 20 - 50 [%]
- **Ambient Temperature range (T min - T max)**: 26 - 33 [°C]
- **Altitude**: 1200 [m]

### Virtual Field Test parameters
- **Water Initial Temperature (T_in)**: 24 [°C]
- **Water Final Temperature (T_fi)**: 99 [°C]
- **Water initial mass (m_w,i)**: 4500 [g]
- **LID**: YES
- **Kind of Fuel**: Wood
- **Moisture Content range (MC min - MC max)**: 7 - 15 [%]
- **Number of Iterations**: 30

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**Progress indicator**: 87% completed

[Run simulation]

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Virtual Field – Stochastic results single task
Virtual Field – Stochastic results single task

![Graph showing specific consumption vs. temperature](image-url)
Virtual Field – Stochastic results multiple tasks
Cook-StEPS v.2.0 Virtual Lab Protocol

Pot Geometry
- Pot Height: 11.5 cm
- Pot Diameter: 19.5 cm
- Pot Weight: 309 g
- Pot Material: Steel

Ambient Condition
- Relative Humidity range (RH min - RH max): 20 - 35 [%]
- Ambient Temperature range (Tamb min - Tamb max): 20 - 28 [°C]
- Altitude: 400 [m]

Test parameters
- Initial Water Temperature (Tw_in): 23 [°C]
- Water initial mass (m_w,in): 2000 [g]
- Useful Power range (P min - P max): 900 - 1200 [W]
- Firepower (FP): 5600 [W]
- Kind of Fuel: Wood
- Moisture Content in Laboratory: 7 [%]
- Number of Simulations: 10

Simulate Protocol
Cook-STePS v.2.0 Virtual Lab Protocol

WBT Average Results

**Protocol Time**

- **Temperature trend over time**

- **Load Chart**

The average power exploited by the three different phases is:

- High Power _cold start_ 967 [W]
- High Power _hot start_ 1045 [W]
- Low Power _simmering_ 726 [W]

The Turn-down Ratio of the stove is: 1,4 [\%]

IWA High Power Thermal Efficiency 17,2 [%]

IWA Low Power Specific Fuel Consumption 0,183 [MJ/min/l]

The average fuel burnt for the three phases is:

- High Power _cold start_ 256 [g]
- High Power _hot start_ 251 [g]
- Low Power _simmering_ 587 [g]
- Total Consumption 1094 [g]

The average water evaporated for the three phases is:

- High Power _cold start_ 66,7 [g]
- High Power _hot start_ 61,7 [g]
- Low Power _simmering_ 670,5 [g]

The Temperature-corrected time to boil is:

- High Power _cold start_ 881 [s]
- High Power _hot start_ 799 [s]
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! ([https://www.researchgate.net/profile/Francesco_Lombardi6](https://www.researchgate.net/profile/Francesco_Lombardi6))