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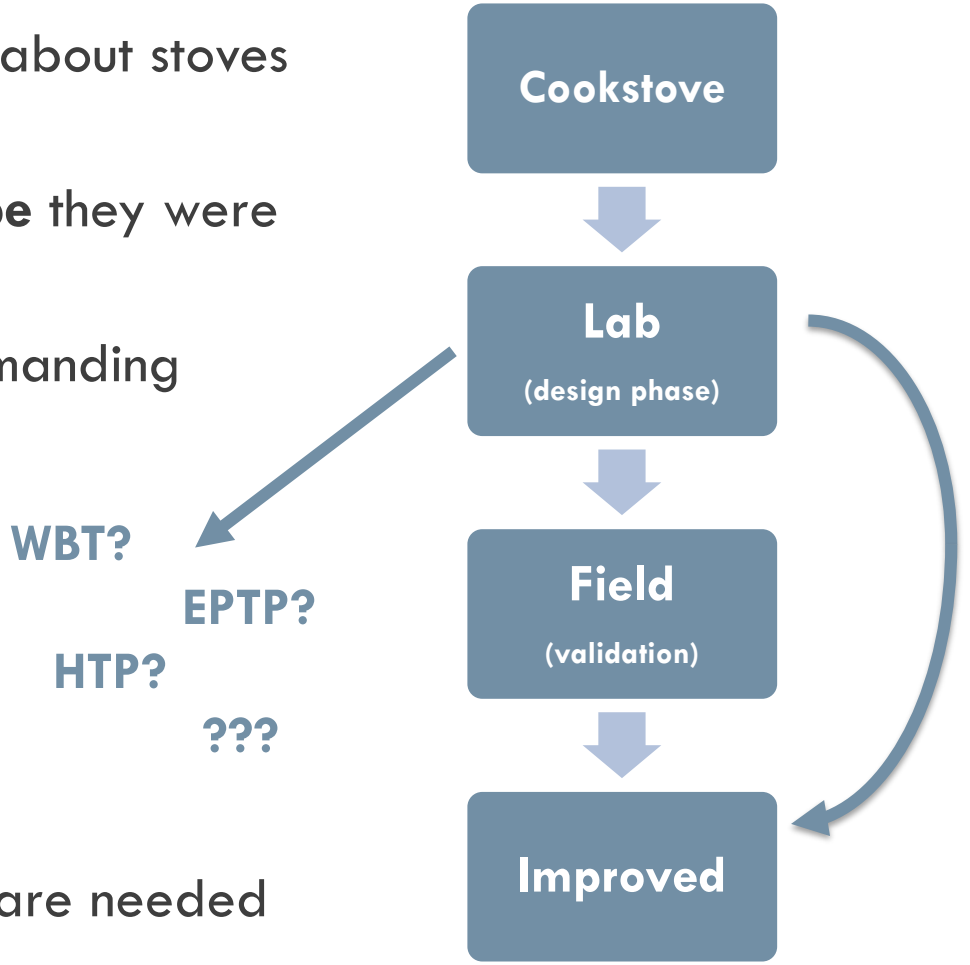
Cook-STePS

Expanding lab tests information by means of thermodynamic simulations

Francesco Lombardi
Doctoral researcher
Department of Energy

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



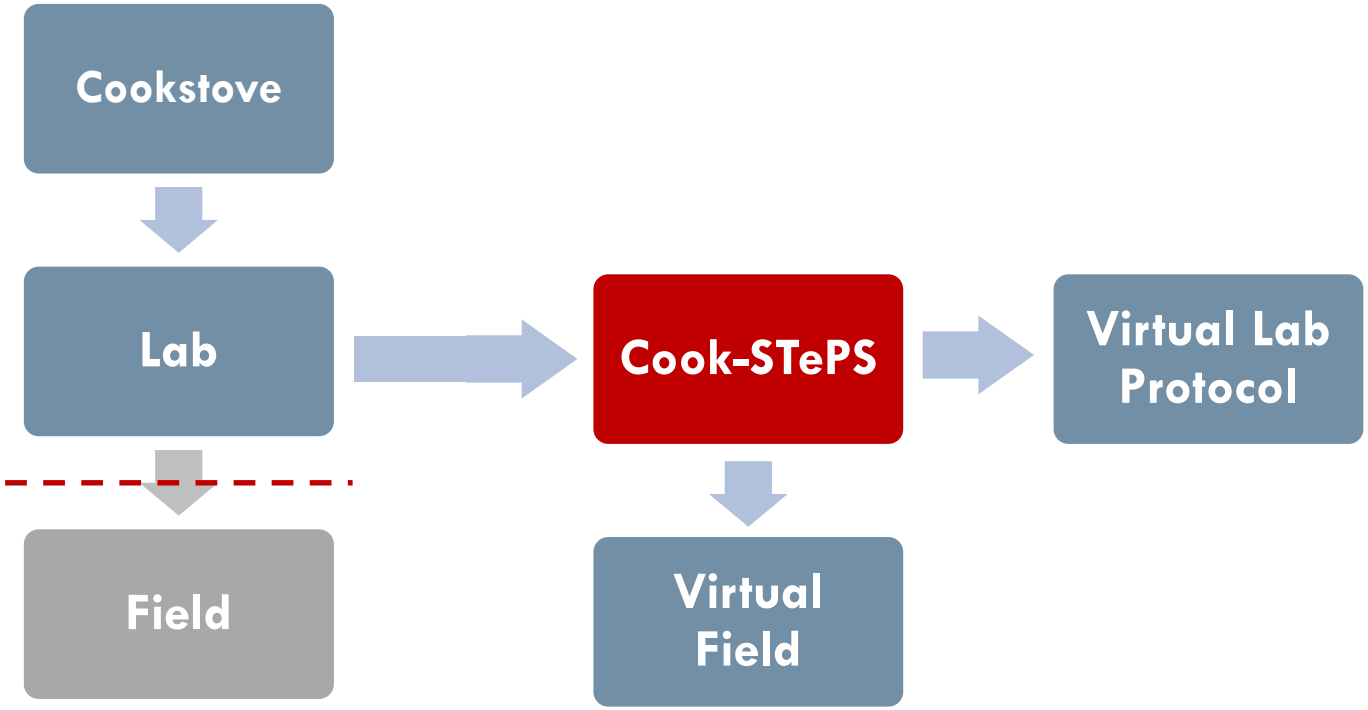
- Morover, **many different lab protocols** are adopted worldwide
- Comparability is hard
- Even in the lab, **many replicates** are needed to ensure statistical significance

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

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. https://doi.org/10.1016/j.energy.2017.11.045



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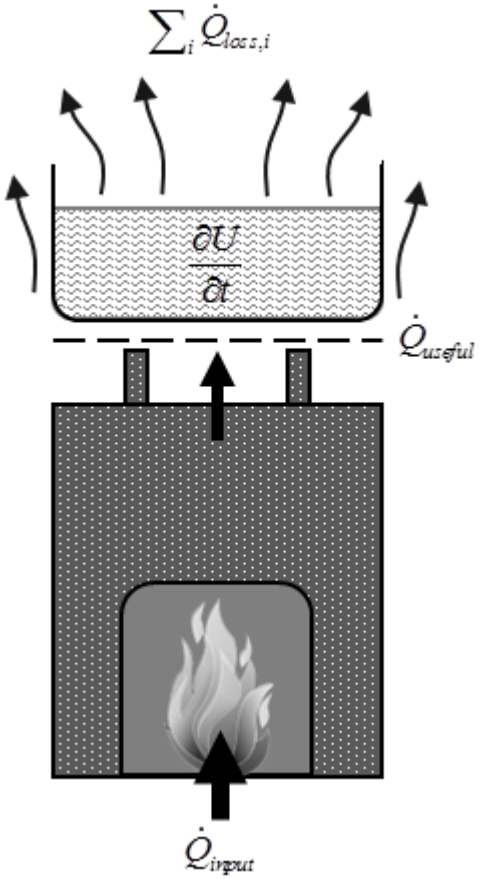


Cook-STePS

Virtual Field

Losses from water surface

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

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

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

Losses from pot sides

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

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

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

$$\dot{Q}_{useful} - \sum_i \dot{Q}_{loss,i} = \frac{\partial U}{\partial t} + \dot{m}_{eva} \Delta h_{eva}$$

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

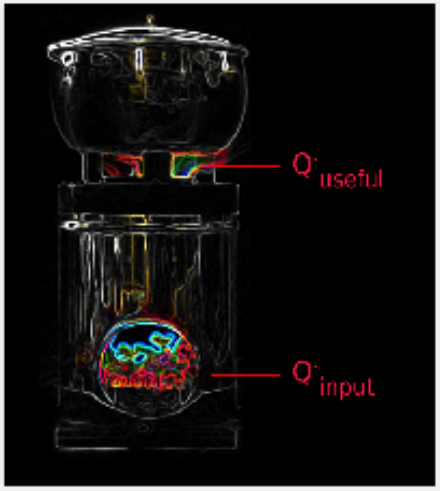
Cook-STePS

Cooking Stoves Thermal Performance Simulator v.2.0

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

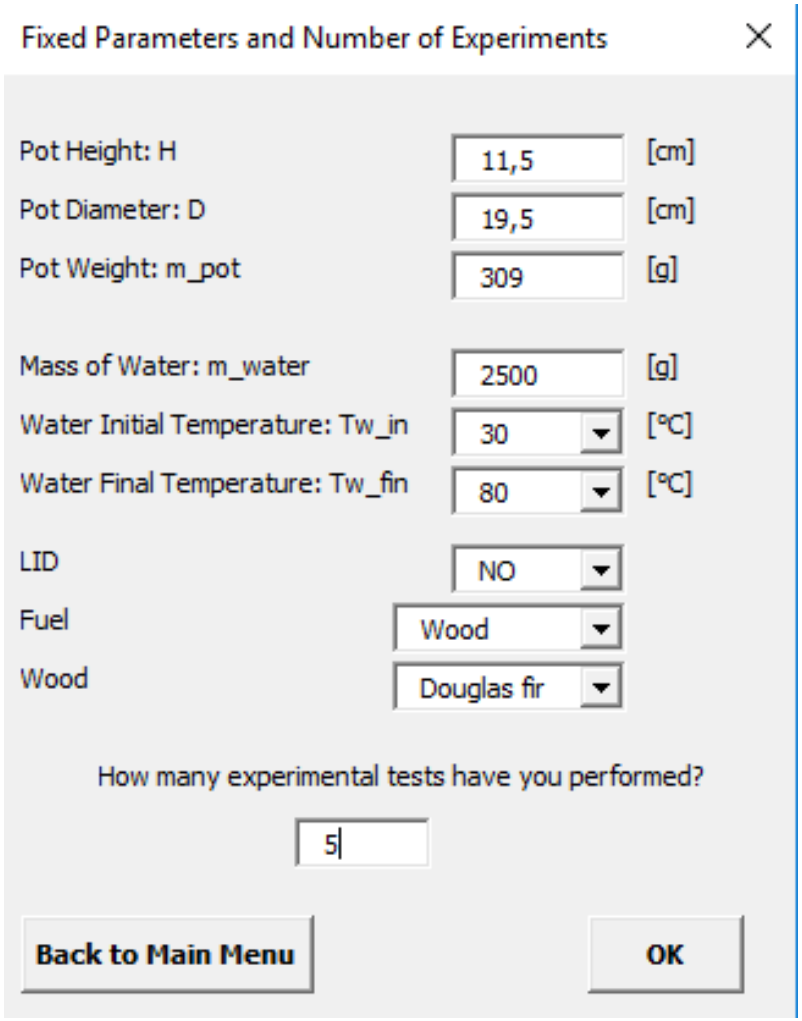
What do you want to do?

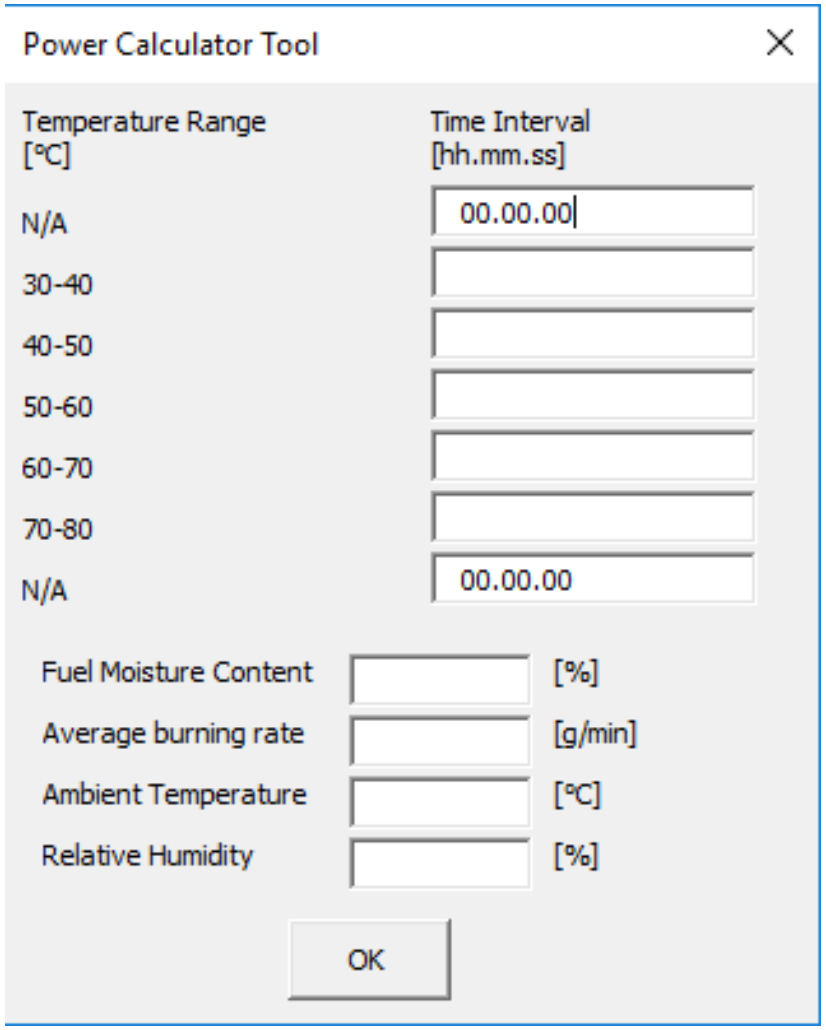
Simulate a Standardized Protocol
Virtual Field Simulation

Proceed with the Simulation

Help

Cook-STePS v.2.0 Power Calculator





Cook-STePS v.2.0 Virtual Field

Virtual Field Simulation - Data Input

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	Douglas fir	
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

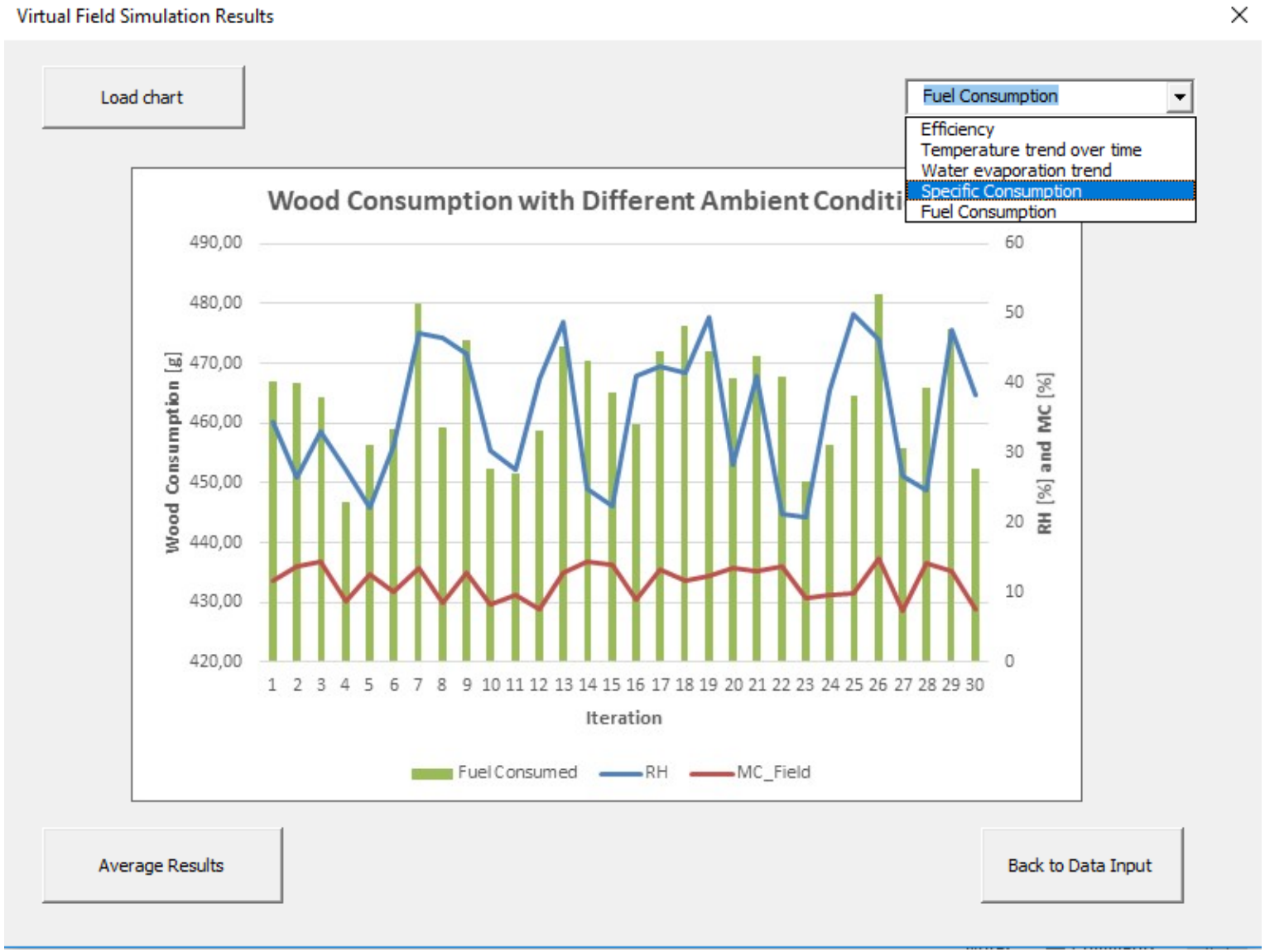
Water Initial Temperature (T_in)	24		[°C]
Water Final Temperature (T_fin)	99		[°C]
Water initial mass (m_w,in)	4500		[g]
LID	YES	Black Pot	☑
Kind of Fuel	Wood	Acacia	
Moisture Content range (MC min - MC max)	7	15	[%]
Number of Iterations	30		

Back to Main Menu | Run simulation

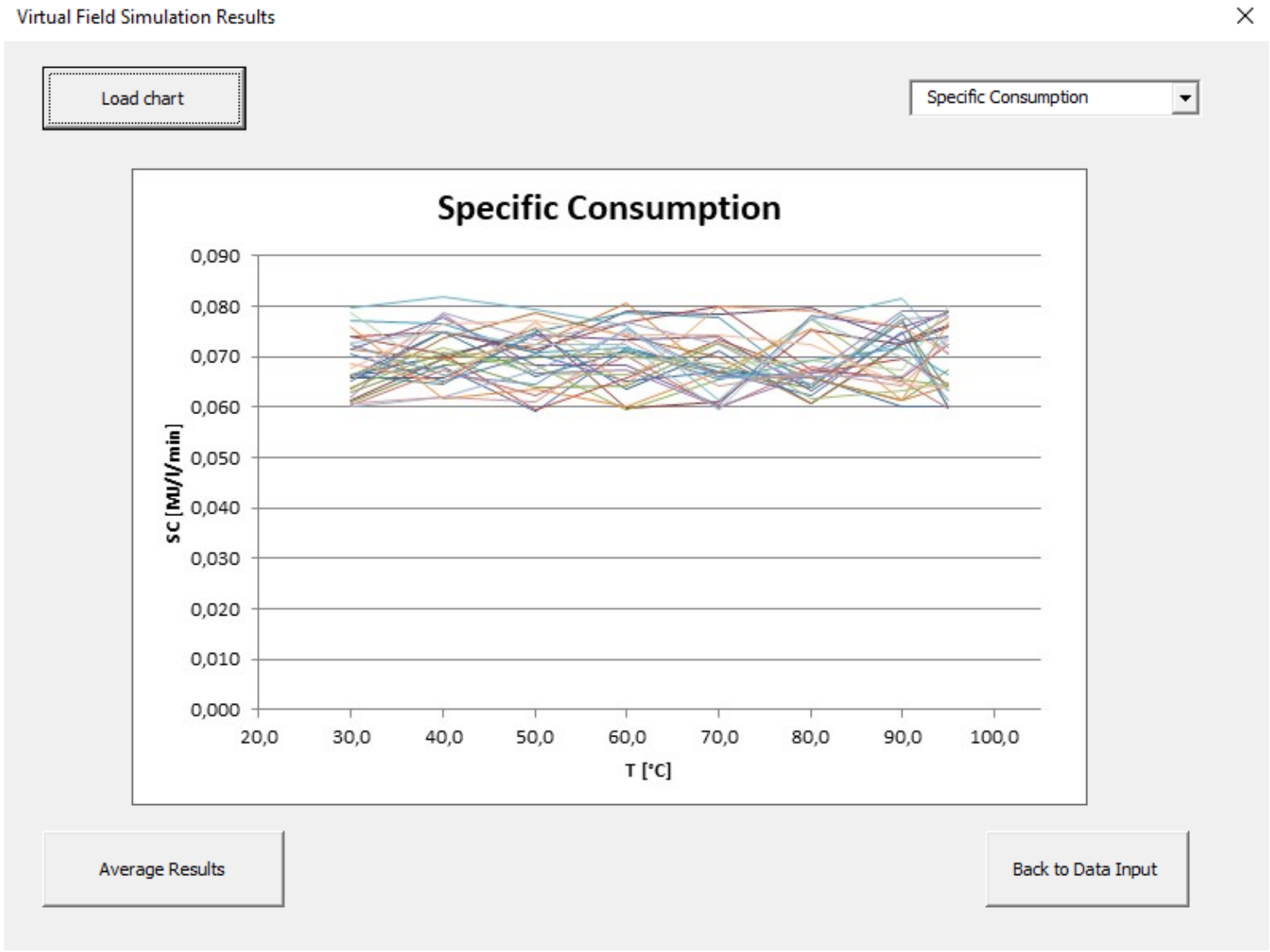
Progress Indicator

87% Completed

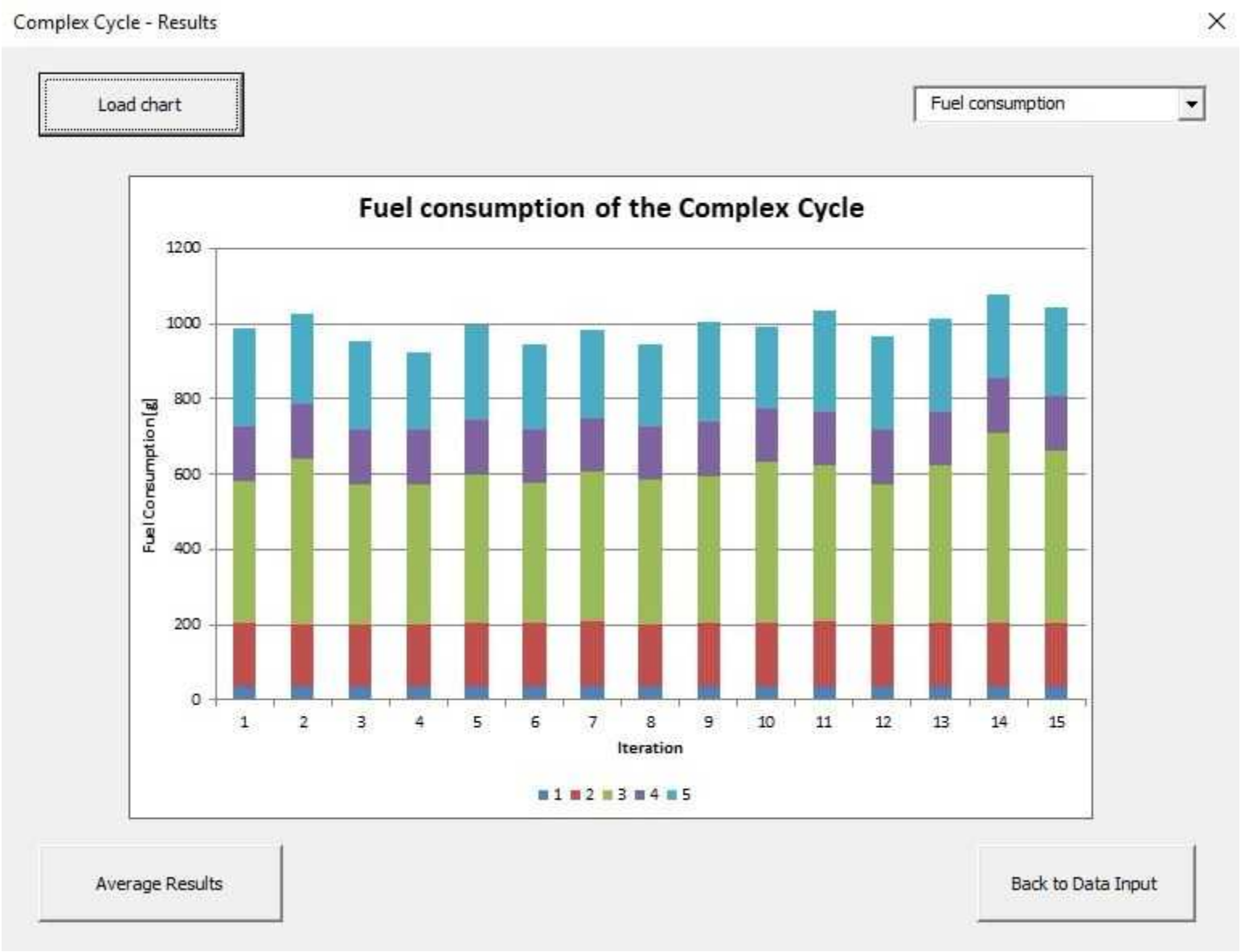
Virtual Field – Stochastic results single task



Virtual Field – Stochastic results single task



Virtual Field – Stochastic results multiple tasks



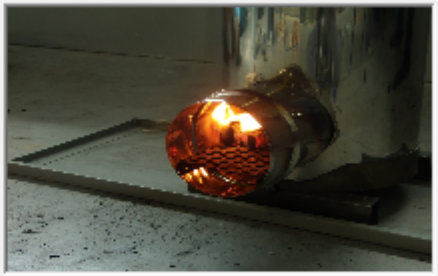
Cook-STePS v.2.0 Virtual Lab Protocol

WBT Simulation

Cook-STePS

Cooking Stoves Thermal Performance Simulator v.2.0

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]

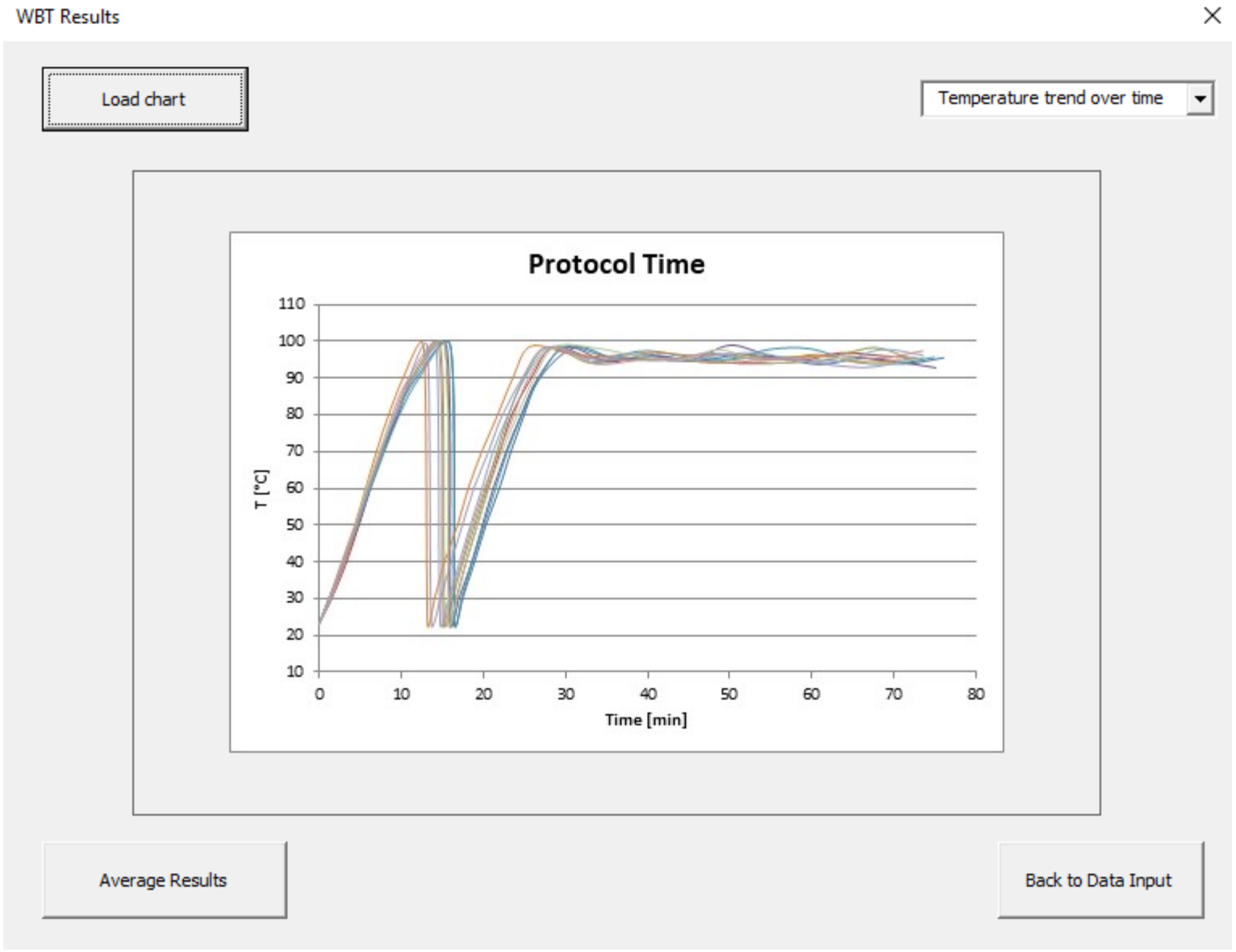
Test parameters

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	Douglas fir	
Moisture Content in Laboratory	7		[%]
Number of Simulations	10		

Back to Main Menu

Simulate Protocol

Cook-STePS v.2.0 Virtual Lab Protocol

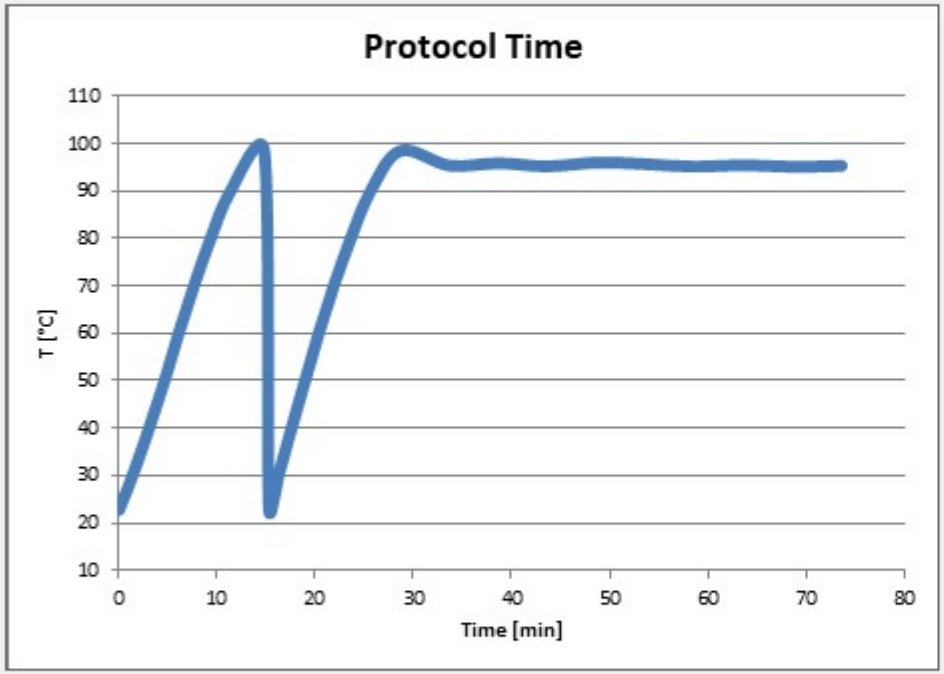


Cook-STePS v.2.0 Virtual Lab Protocol

WBT Average Results

Load Chart

Temperature trend over time



Back to Detailed Results

Back to Data Input

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)