MACC Dashboard: Technical Documentation

Last update: 6 June 2025

1 Overview

This document outlines the structure of the MACC (Marginal Abatement Cost Curve) Dashboard, a tool designed to assess agricultural water-saving interventions. The application integrates investment costs, multiple streams of benefits (water, energy, yield), and policy instruments (tariffs and subsidies) into a cost-effectiveness framework.

2 Assumptions

2.1 Investment Horizon

Each intervention is assessed over a fixed time horizon T (typically 10 years), which reflects the expected operational lifespan of the measure.

2.2 Discounting

All future benefit streams are discounted to present value using a social discount rate $r = 0.035$.

2.3 Cost Structure

Total cost C_{tot} includes implementation costs per hectare scaled by area and adjusted for policy subsidies. A constant proportional subsidy s can be applied.

2.4 Benefit Streams

Benefits are annualized and additive, they are comprised of:

- Water savings
- Energy savings
- Yield improvements

2.5 Adoption Pathway

The model simulates partial adoption over time using a simple exponential adjustment toward a potential area A_{pot}, governed by an adaptation coefficient α.

3 Analytical Model

4 Analytical Model (Revised)

Let:

- C_{ha}: Cost per hectare [USD/ha]
- A_{pot}: Potential adoption area [ha]
- γ: Adoption rate (logistic function parameter) [1/year]
- t_{mid}: Midpoint year (50% adoption)
- δ: Social discount rate (e.g., 0.035) [1/year]
- T: Investment horizon [years]
- s: Subsidy rate (e.g., 0.2) [unitless]
- $WS(t)$: Annual water savings [m^3/year]
- $B(t)$: Total annual benefit at time t [USD/year]
- $A(t)$: Area adopted at time t [ha], with:

$$A(t) = \frac{A_{\text{pot}}}{1 + e^{-\gamma(t - t_{\text{mid}})}}$$

4.1 Cost Adjustments Over Time

Annual investment cost assuming per-hectare cost and time-distributed adoption:

$$C(t) = C_{\text{ha}} \cdot \frac{dA(t)}{dt} \quad \text{[USD/year]}$$

Subsidy-adjusted present value of investment cost:

$$PV_{\text{cost}} = (1 - s) \cdot \int_0^T C(t) \cdot e^{-\delta t} \, dt$$

4.2 Present Value of Benefits with Dynamic Adoption

Total annual benefit based on area adopted:

$$B(t) = b_{\text{unit}} \cdot A(t) \quad \text{[USD/year]}$$

where b_{unit} is the per-hectare benefit [USD/ha/year].

Present value of total benefits:

$$PV_{\text{benefit}} = \int_0^T B(t) \cdot e^{-\delta t} \, dt$$

4.3 Equivalent Annual Cost and Marginal Cost

Net present cost:

$$\text{Net Cost} = PV_{\text{cost}} - PV_{\text{benefit}} \quad \text{[USD]}$$

Equivalent Annual Cost:

$$EAC = \frac{\delta \cdot \text{Net Cost}}{1-(1+\delta)^{-T}} \quad \text{[USD/year]}$$

Average annual water savings:

$$\overline{WS} = \frac{1}{T}\int_0^T WS(t)\,dt \quad [\text{m}^3/\text{year}]$$

Marginal Cost per m^3 saved:

$$MC = \frac{EAC}{\overline{WS}} \quad [\text{USD/m}^3]$$

4.4 Policy-Adjusted Price Benchmark

$$P_{\text{eff}} = \max(P_{\text{market}}, P_{\text{tariff}}) \quad [\text{USD/m}^3]$$

$$\text{Cost-effective if: } MC \le P_{\text{eff}}$$

5 Interpretation of Outputs

5.1 MACC Visualization

- **X-axis**: Cumulative water savings (m^3)
- **Y-axis**: Marginal cost per m^3 saved (USD)
- **Bars**: Each represents a distinct measure
  - Green: Cost-effective ($MC \le P_{\text{eff}}$)
  - Orange: Not cost-effective
- **Dotted line**: Policy-adjusted water price (tariff or market)

5.2 Key Insights

- Measures with **negative marginal cost** indicate net economic benefit — priority investments.
- Measures just above P_{eff} may be viable with small subsidies or price adjustments.

5.2.1 Negative Marginal Costs: Explanation and Diagnostics

Several measures in the MACC exhibit **negative marginal costs (MC)**, which implies that the present value of total benefits (including water, energy, and yield improvements) **exceeds the cost of implementation**. These interventions not only save water but also generate net economic gains, and are thus considered **"no-regret" options**.

This outcome arises from the underlying cost formula:

$$\mathrm{MC} = \frac{\mathrm{EAC}}{\mathrm{WS}} \quad \text{where} \quad \mathrm{EAC} = \frac{r \cdot (\mathrm{C}_{\mathrm{sub}} - \mathrm{PV}_{\mathrm{benefit}})}{1 - (1+r)^{-T}}$$

When $\mathrm{PV}_{\mathrm{benefit}} > \mathrm{C}_{\mathrm{sub}}$, the net cost becomes negative, driving down the marginal cost.

Policy Implications: These results justify prioritizing such interventions even without financial incentives, as they enhance both economic returns and water efficiency. Additionally, the MACC helps identify borderline cases where modest policy adjustments (e.g., small subsidies or water tariffs) could tip interventions into cost-effectiveness.

6 Simulation Modules

6.1 Adoption Dynamics

Adoption over time is modeled using a logistic function, which is influenced by:

- The adoption rate parameter (`adoption_rate`), defining the speed of uptake
- The midpoint year (`midpoint`), when 50% adoption is achieved

The area under adoption at time t is given by:

$$A(t) = \frac{A_{\mathrm{pot}}}{1 + e^{-r(t - t_{\mathrm{mid}})}}$$

where A_{pot} is the potential adoption area, r is the adoption rate, and t_{mid} is the midpoint year.

6.2 Benefit Simulations

Given the dynamic adoption, the app simulates the following:

- **Energy Savings:** proportional to area adopted relative to potential
- **Yield Benefit:** scaled linearly by adopted area
- **Total Benefit:** additive sum of water, energy, and yield benefits per year