Farm-Hand

Farm-Hand is an affordable smart irrigation system that provides 'right-time, right-volume' irrigation to crops. Aimed at farmers in water-stressed India, it uses smartphones to change wasteful practices like leaving water pumps on all day and can mitigate unproductive conditions by using advanced weather forecasting and soil condition monitoring, in conjunction with local know-how.

54% of the Indian subcontinent faces extremely high levels of water stress, impacting on the economic and nutritional wellbeing of a rural population amassing nearly 900 million people. With small scale agriculture a ubiquitous practice across much of rural India, it has been estimated that at present 90% of freshwater withdrawal can be attributed to farming practices often carried out with limited inefficient technologies and poor irrigation practices. Farm-Hand's cloud based micro-irrigation system has been piloted in these circumstances and shown to reduce total water use by up to 80% whilst doubling crop yields.

Combining a highly localised weather forecasting system with know-how on soil conditions and irrigation needs, local farmers' knowledge is stored on a distributed cloud-based system where weather forecasts, soil moisture conditions, evaporation modelling and grid-outage information continually adapt local irrigation schedules to provide optimal water volume and timing.

Key points:
Smart '*right-time, right-volume*' irrigation system aimed at rural Indian smallholdings
50% reduced water consumption
Crop Yields increased by nearly a third
10% reduction in fertiliser use

The Farm-Hand Smart Irrigation System

Approximate Specifications per Farm-Hand Application:

Typical Application Area	*2-Acre Rural Smallholding*
Target Application	*Rural India; Tamil Nadu State*
Water Use Reduction	*50%*
Energy Use Reduction	*50%*
Fertiliser Use Reduction	*10%*
Crop Yield Increase	*30%*
Business-As-Usual Alternative	*An equivalent 2-Acre Smallholding operating a 1kW mains-connected water pump, at full flow, for an average of 4 hours per day during the (approximate) Tamil Nadu growing season*

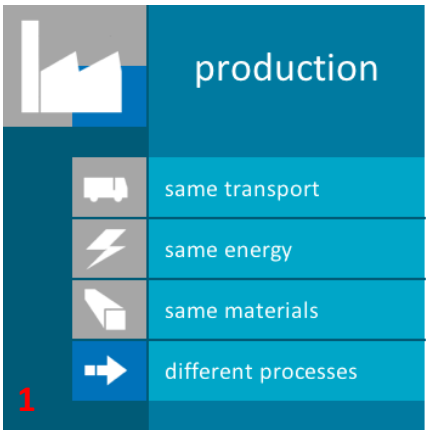
Robert Fraser Williamson &
Eduardo Rosales Ortega

Calculations

With the help of the Climate-KIC tool, the following carbon savings for the Farm-Hand Smart irrigation system were calculated. As the product's business model is still in development, it should be noted that the following carbon calculations are estimations; reasonable, informed assumptions are made clear where made.

Savings from 1 Business Unit:

One 'Business Unit' is defined here as the application of the Farm-Hand irrigation system over one calendar year on a 2-Acre smallholding in Tamil Nadu State in the South of India, over the course of the growing season. It replaces a 'Business as Usual' (BAU) alternative of the same 2-acre smallholding operating a 750W self-priming centrifugal irrigation pump water pump at full-flow for an average of 4 hours per day during the (approximate) growing season of Tamil Nadu (assumed as 200 days). This corresponds to an assumed energy usage of 3kWh per day in the state-subsidised electrical provisions for irrigation energy across Tamil Nadu, accumulating to 600kWh across a nominal operational year.



As shown above, compared to the Business as usual scenario, the Farm-Hand system uses the same transport, energy and materials with different processes during the production phase (**1**). This is due to the product essentially having a very light material footprint in production, with only small valves and a microprocessor the difference with the traditional alternative; Farm-Hand essentially uses the same pumps, pipes, electricity and water supplies in production. Although the product may in practise involve the upgrading of degraded irrigation components, for the purposes of this audit the Farm-Hand system is assumed to have equal energy-inputs in production as the BAU alternative. The 'different processes' included in the IdeMat programme represent the water savings of the Farm-Hand system once in operation for irrigation; due to the macros involved and the product's multiple benefits in energy and 'food' inputs in use, containing water usage as a process was the best methodology to fully represent the embodied Carbon savings found therein.

During Use (**2**), the Farm-Hand system represents a clear and significant environmental improvement over the BAU alternative. The system reduces overall water consumption by approximately 50%, translating to Xl of water per year per 2-Acre smallholding. Furthermore, the IdeMat programme captures a greatly reduced electricity use from pump-operation is reduced 600kWh per annum due to the Smart system providing water exactly *when* it can be productively absorbed by soils and crops. It is important to note that these electricity savings are in respect to the average electricity grid-emissions factor for rural Tamil Nadu state, provided largely by poor-quality high-lignite concentration thermal coal plants. The Farm-Hand system also facilitates a 10% reduction in non-organic fertiliser application during the use phase; based on an assumed application rate of 100kg/Ha, the total previous use was 80.97kg per year per 2-Acre smallholding. For the purposes of clarity and simplicity, this 10% saving has been extended to the reduced use of non-organic pesticides in use at 2.8kg/Ha extending to a previous use of 2.27kg per BU. Despite these increases in water, energy and fertiliser efficiency, the system as a whole is able to institute a 30% improvement in overall crop yield. Further analysis is required to refine this figure across different crop varieties and regional applications. With regards to water usage, 7,722.24 litres per hour flow rate was applied to the typical Tamil Nadu irrigation mechanism, a figure derived from the generalised data available from the Indian Central Water Commission and Ministry for Agriculture. This corresponds to a total of 6,177,792 litres

of irrigation use per year representing the 50% saving that the Farm-Hand system brings. Within the IdeMat programme, the corresponding embodied emissions attributed to this water saving in Use were found to be best represented by the category of 'processes involving wastewater' which applies a factor to the values above, but equates to the same Carbon saving.

At the end-of-life phase (**3**) the Farm-Hand system is assumed as embodying equal energy as the BAU alternative, although the programme captures a stylised representation of the greatly improved soil fertility and agricultural productivity under the set of conditions 'more composting'. However, it should be noted that although the product has a similar material footprint and waste production as the BAU alternative, it is closely associated with a more holistic and efficient use of agricultural land. Although not 'End-of-Life' in a product-sense, Farm-Hand reduces the volume of Nitrogenous run-off from fertiliser use, a key and growing environmental pollutant in the region due to excessive application of fertilisers. Furthermore, by applying irrigation by the 'right-time, right-volume' model the Farm-Hand system greatly improves soil fertility and organic content (a driver behind increased crop yields) which has a cyclical benefit over time on water retention and irrigation requirements, and also (to a lesser extent) on the Carbon sequestration potential of the soil. With these differences between the BAU scenario with this new and innovative solution, the Greenhouse Gas impacts of Farm-Hand's product can quantified in the table below (also represented in the lifecycle diagram further in the report). Using the quantified differences from the business as usual, the carbon footprint of 1 Farm-Hand Business Unit (2-Acre application of irrigation system over 1 calendar year) is as follows:

	Difference	Category	LCI process	kg $CO_{2\,eq}$		per
	new processes in production:	wastewater	average wastewater	+	1.352	kg
	instead of:	wastewater	average wastewater	-	1.352	kg
	less energy during use:	fossile electricity	Powerplant lignite (=heat)	-	0.327	MJ
				-		
	less food production of:	inorganic fertilisers	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0	-	2.126	kg
		pesticide	Idemat2016 Pesticides (unspecified)	-	10.777	kg
	more composting of:	compost	average compost	+	-0.309	kg

Qty. per BU	Unit	Difference and LCI	LCI kg $CO_{2\,eq}$	scalar	kg $CO_{2\,eq}$ per BU
3088.9	kg (kilogram)	new processes in production: average wastewater	0,001 per kg	3088.896	4176.85
6177.8	kg (kilogram)	instead of: average wastewater	0,001 per kg	-6177.79	-8353.71
600.0	kWh (kilowatt	less energy during use: Powerplant lignite (=heat)	0,000 per MJ	-2160	-706.99
8.1	kg (kilogram)	less food production of: Ammonium nitrate, as 100	0,002 per kg	-8.097	-17.21
0.2	kg (kilogram)		0,011 per kg	-0.227	-2.45
300.0	kg (kilogram)	more composting of: average compost	0,000 per kg	300	-92.66

When calculated, the impact reduction of 1 application is **4,996.17kgCO_2e**. This is a significant Carbon saving largely attributable to the improvements in water and energy efficiency of the Farm-Hand system in the Use phase. For example, around **4,176.86kgCO_2e** mitigation can be ascribed to the reduced water consumption alone. This is an especially pertinent figure given the extreme water-stress that much of Tamil Nadu and rural India is projected to experience with increasing frequency in the coming decades. Tamil Nadu is projected to receive between 9.4% and 5.0% reduced rainfall by 2050, with a minimum expected temperature increase of between 2.1°C and 3.3°C in the state.

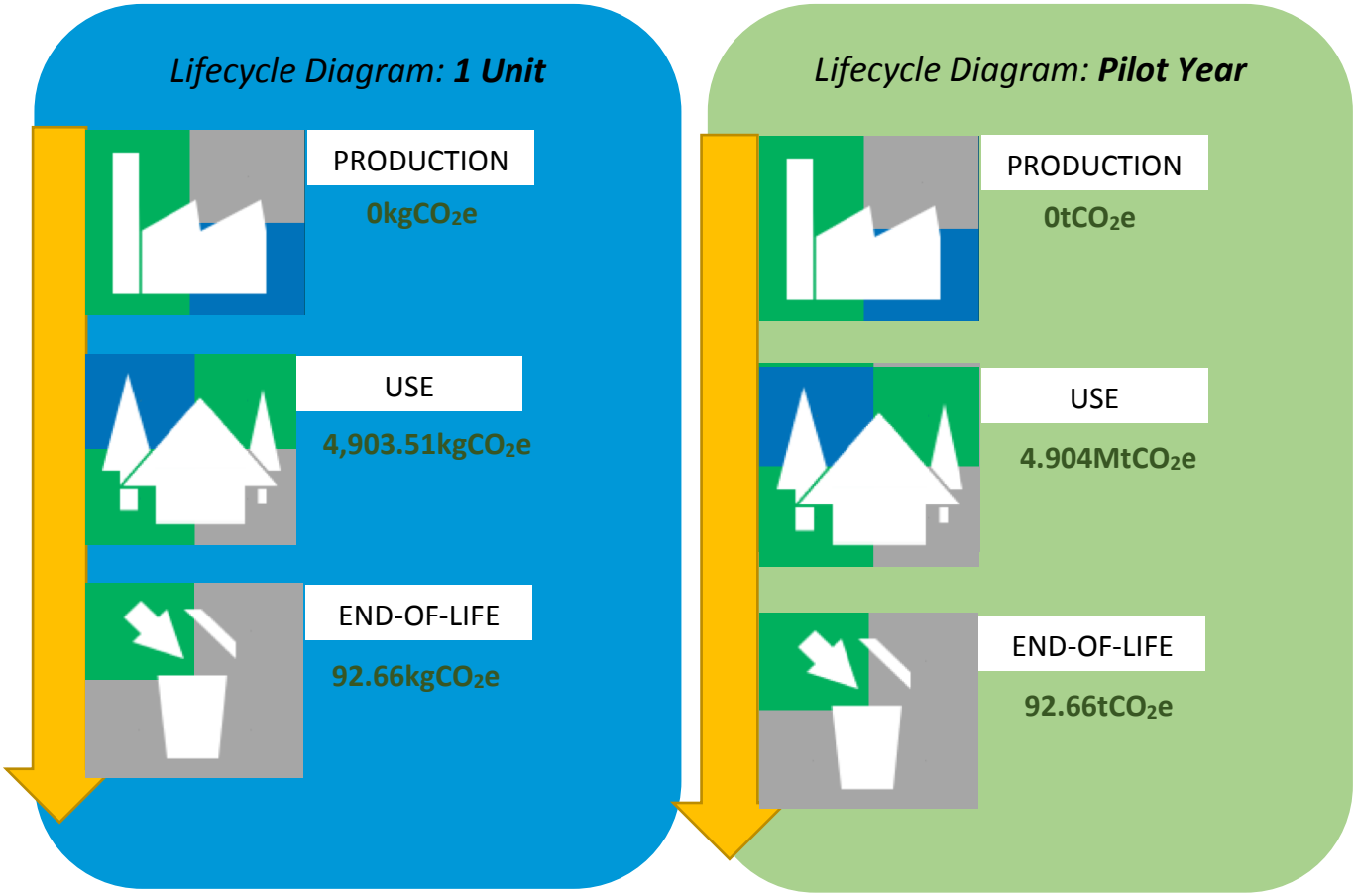
Pilot Year (1,000 Units):

The total carbon footprint forecast for a nominal pilot application of 1,000 Farm-Hand irrigation systems is **4,996,170kgCO_2e**, or **4.99MtCO_2e**. This translates to driving around the world 618 times, burning 9,704 barrels of oil, or 952 elephants (see table below).

Carbon Footprint Forecast for Farm-Hand pilot application :		impact reduction of:	-5E+03 kgC
Other impacts than carbon footprint per Farm-Hand pilot application	human health:	impact reduction of:	-8.30 euro
	eco-toxicity:	impact reduction of:	-37.91 euro
	resource depletion:	impact reduction of:	-3.31 euro

Total Carbon Footprint of 1000 Farm-Hand BU's per year:						-5.0E+06 kg $CO_{2\,eq}$
4996	618	5042	9704	2100	952	901
ton CO_2	times driving a car around the world	passengers flying London-New York	barrels of oil burnt	EU households annual electricity	elephants mass of CO_2	hot air balloons filled with CO_2

At this relatively early stage of product and business-model development, every 2-acre application is projected to save **50 euros** in negative externalities associated with the prevailing BAU alternative; these are aggregated across impacts to human health, environmental contamination and pollution, and resource depletion. Given the relatively small material footprint and value of each unit, this is an impressive total and as a business model can be seen as having significant potential to ameliorate (in part) the projected difficulties Tamil Nadu will face in water stress and groundwater shortages. The Lifecycle Diagrams shown below (for both an individual application and the 1000-unit pilot year) are shown below.



Associated Statistics on Indian Agricultural Economy and Population:

CONDITION	PREVALENCE (%)
Low Birth Weight	22.00
Iron Deficiency	70.00
Underweight	42.60
Stunting	48.00
Wasting	20.00

Prevalence of child healthcare issues across whole Indian population (World Bank, 2015)

	GLOBAL	INDIA	EU
Total Population	86.25%	74.04%	99.32%
Female (15-24)	82.66%	81.85%	99.74%
Male (15-24)	92.75%	90.08%	99.74%
Female (adult)	82.66%	59.28%	98.91%
Male (adult)	89.84%	78.88%	99.32%
Youth	91.36%	86.15%	99.74%
Adult	86.25%	69.30%	99.11%

International Literacy Rate Comparisons (World Bank, 2016)

	Season Duration		Max Leaf Area Index	
	Maize	Wheat	Maize	Wheat
Present	157	123	2.58	3.66
2020	152	117	2.62	3.54
2050	143	108	2.58	3.34
2080	135	100	2.52	3.05

Reductions in crop productivity & season (Aggregated from: GOB, 2014; GOI, 2015; Kumar-Bal, 2016; Reserve Bank of India, 2012)

Crop	2000-2003 Triennium Average Yield (kg/ha)	2007-2010 Triennium Average Yield (kg/ha)	Change (%)
Total Cereals	1732	1778	3
Total Rice	1457	1353	-7
Total Maize	2384	2629	10
Total Course Cereals	979	1948	99
Total Pulses	901	1061	18

Changes in crop yield productivity corelated with increasing fertiliser application (ibid)

Future Recommendations

Incorporate improvements to existing irrigation technology in business model. Many of the environmental benefits of Farm-Hand's product are attributable to the Smart, cloud-based programmes that enable greater efficiency. These gains could be complimented by associated maintenance and upgrades to existing pipes, valves and sprinklers which are often in a poor state of repair and contribute to water-use inefficiency over time. These are low cost improvements likely to produce large gains in water efficiency, and can be cost-effectively incorporated into the installation-phase of Farm-Hand's product using local labour.

Collaborate with irrigation technology companies. There is a great potential for the modelling and software of the Farm-Hand product to be combined at commercial scale with existing agricultural equipment and services providers, who have access and engagements with a wide and growing market of small-medium scale farms. Alternatively, engaging with 'Farmer Producer Organisations' in India and developing states would allow Farm-Hand to engage with the application of their technology at scale and may provide more cost-efficient opportunities for large Carbon savings.

Associated programme of user education & feedback. Rural India has proven a testing area for climate policy, with many State (and the Federal Govt.) engaging with 'Behaviour Change Techniques' to combat a lack of education, literacy and cultural barriers to efficient low-carbon economic activities. Farm-Hand's product is ideally placed as a 'ground-up', user orientated technology that can allow rural farming populations to engage with innovative technologies and practices. Farm-Hand could provide a mechanism for training, outreach and ongoing feedback within the same user-platform that the system runs from.

Integration with wider Energy Matrix Decarbonisation. India has seen a recalcitrant lack of progress in the agricultural sector over economic and technical decarbonisation. This can in part be attributed to the *heavily-or-wholly* subsidised electricity that is given to farmers, almost entirely from coal and lignite based thermal power plants with very high grid emissions factors. Any incentive to use water pumps more efficiently is also mitigated by this free source, so Farm-Hand could engage and coordinate with local communities, cooperatives, NGO's, and Farmer Producer Organisations to lobby state and federal government over the carbon intensity of support offered to farmers.

ecci EDINBURGH CENTRE FOR CARBON INNOVATION

eit Climate-KIC