National Artificial Intelligent Dairy Energy Application (NAIDEA)

User Manual 1.0

This project has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2019, Grant number 19/RDD/453.

Introduction

NAIDEA was developed as a demonstrative tool that integrates macro-level survey information collected on Ireland's population of dairy farms with artificial neural network models developed to simulate total, milk cooling, milk harvesting and water heating electricity use using easily attainable farm details. These models were trained using monitored consumption data, milk production, stock data and infrastructural data collected over six years on 74 pasture-based dairy farms, and validated using nested cross-validation. The methodology also employed hyper-parameter tuning and multiple variable selection techniques to identify the farm details that maximized prediction accuracy, that could then be collected as part of nationwide farm surveys.

NAIDEA was developed using data from typical Irish grass-based milk producers and can only be utilized within the scope of the data used for model training. For example, NAIDEA is not suitable for data relating to rotary, or robotic milking systems, or farms that operate a confinement based dairy system.

NAIDEA is a desktop application offering:

1. Import/export functionality, that allows users to import data (.csv) required for generating energy predictions using five pre-trained artificial neural network models, export the processed dataset and results including farm-level Dairy Energy Ratings as well as input a carbon intensity value (gCO2/kWh) to ensure carbon emission calculations are always up to date.
2. Macro-level energy statistics on Ireland's population of dairy farms, that can be monitored over time to calculate the effectiveness of changes to government policy. E.g. electricity consumption per litre
3. A filtering mechanism was also incorporated to allow users to filter energy statistics according to farm size or the presence of energy technologies such as plate coolers or variable speed drives. This allows government bodies to calculate energy statistics for specific dairy farm demographics.
4. A Dairy Energy Rating for each farm, allowing farms that are using energy efficiently or inefficiently to be easily identified, allowing government bodies to then direct those dairy farms using energy inefficiently towards the existing suite of decision support tools such as the Agricultural Energy Optimisation Platform.

NAIDEA's targeted approach can help fast track the proliferation of energy efficient and renewable energy technologies to help offset agri-related emissions while having the added benefit of 1) reducing the electricity demand from the electrical grid, 2) increasing the penetration of renewable energy contributing to overall demand, and 3) allowing farmers to become more energy independent, thereby reducing the impact of future increases in energy prices on production costs. NAIDEA has been developed in collaboration between Munster Technological University, Bord Bia, the Sustainable Energy Authority of Ireland and Teagasc.

Contents

Accessing NAIDEA

The most recent standalone executable file can be found at: https://doi.org/10.5281/zenodo.6511392. Just download and open the NAIDEA_windows.exe file and follow the installation guidelines (currently only available for windows systems).

NAIDEA overview

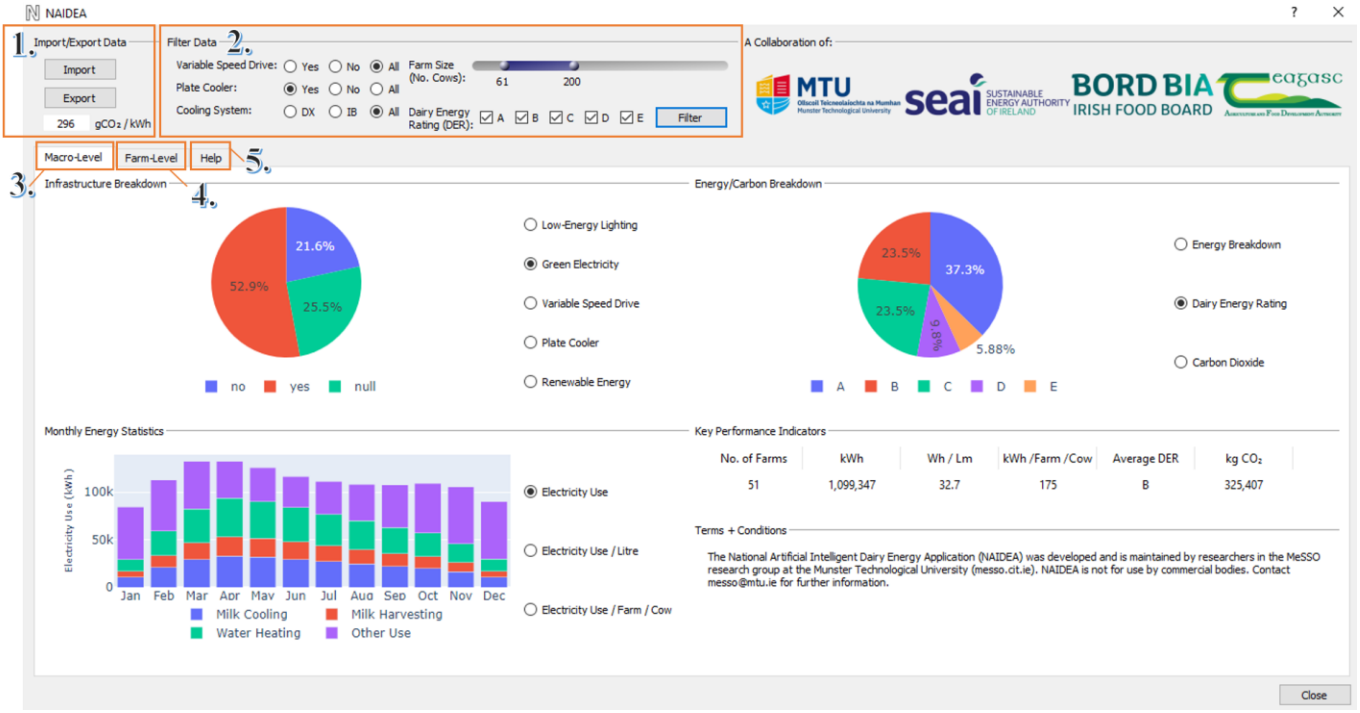


Figure 1 NAIDEA's macro-level section user interface

NAIDEA's GUI has five primary components including:

1) An import/export section, that allowed users to import data (.csv) required for generating energy predictions using five pre-trained ANN models, export the processed dataset and results including farm-level DERs as well as input a carbon intensity value (gCO_2/kWh) to ensure carbon emission calculations are always up to date. The positioning of this section is shown via label 1 in Figure 1.

2) A filtering section whereby users may select and/or deselect a subset of dairy farms based on each farm's installed infrastructural equipment such as the type of milk cooling system (direct expansion (DX) or ice bank (IB)), whether a variable speed drive was installed (yes or no), and whether a plate cooler was installed for milk pre-cooling (yes or no). In addition, the imported dataset could also be filtered according to herd size (the total number dry and lactating dairy cows), and DER (A to E). The positioning of this section is shown via label 2 in Figure 1, with a closeup shown in Figure 2.

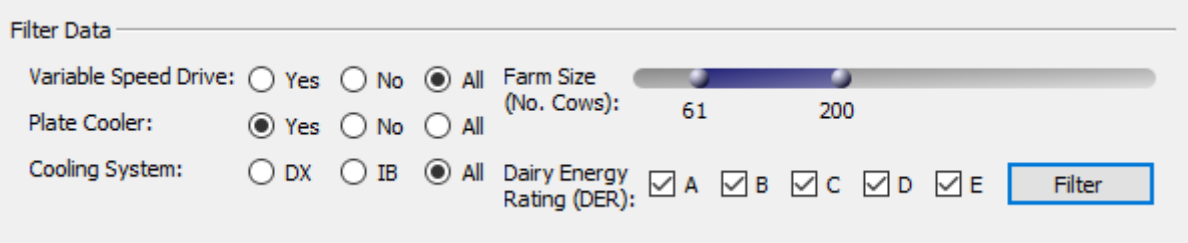


Figure 2 NAIDEA's data filtering component

3) A macro-level statistics section comprised of five sub-sections containing charts and figures resulting from the imported dataset and filter section parameters. These sub-sections were: *infrastructural breakdown*, *energy/carbon breakdown*, *monthly energy statistics*, *key performance indicators* (KPIs), and *terms and conditions.* The infrastructural breakdown sub-section allowed users to generate pie charts relating to the utilization of low-energy lighting, "green" electricity, variable speed drives, plate coolers and renewable energy technologies. A closeup of the infrastructural breakdown sub-section shown in Figure 3. The energy/carbon breakdown sub-section allowed users to generate pie-charts relating to the electrical energy use and energy-related carbon emissions of each major electricity consuming process on the dairy farm (e.g. milk cooling, milk harvesting and water heating). In addition, the distribution of calculated DERs amongst the selection of farms may also be displayed as a pie chart. The monthly energy statistics consisted of a stacked bar chart that displayed cumulative electricity consumption (kWh), electricity consumption per litre (Wh/Litre) or electricity consumption per dairy cow (kWh/cow). The key performance indicators sub-section displayed a table consisting of the number of selected farms (as per filtering parameters), the cumulative electricity consumption, electricity consumption per litre (Wh/Litre), electricity consumption per dairy cow (kWh/cow), the mean DER, and kg of energy related carbon emissions (kg CO_2). A closeup of the key performance indicator table is shown in Figure 4. Lastly, a sub-section presenting NAIDEA terms and conditions is also displayed. The positioning of this section is shown via label 3 in Figure 1.

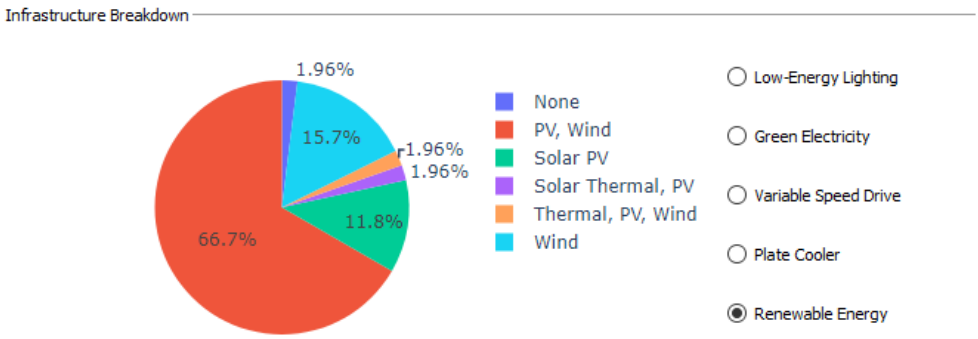
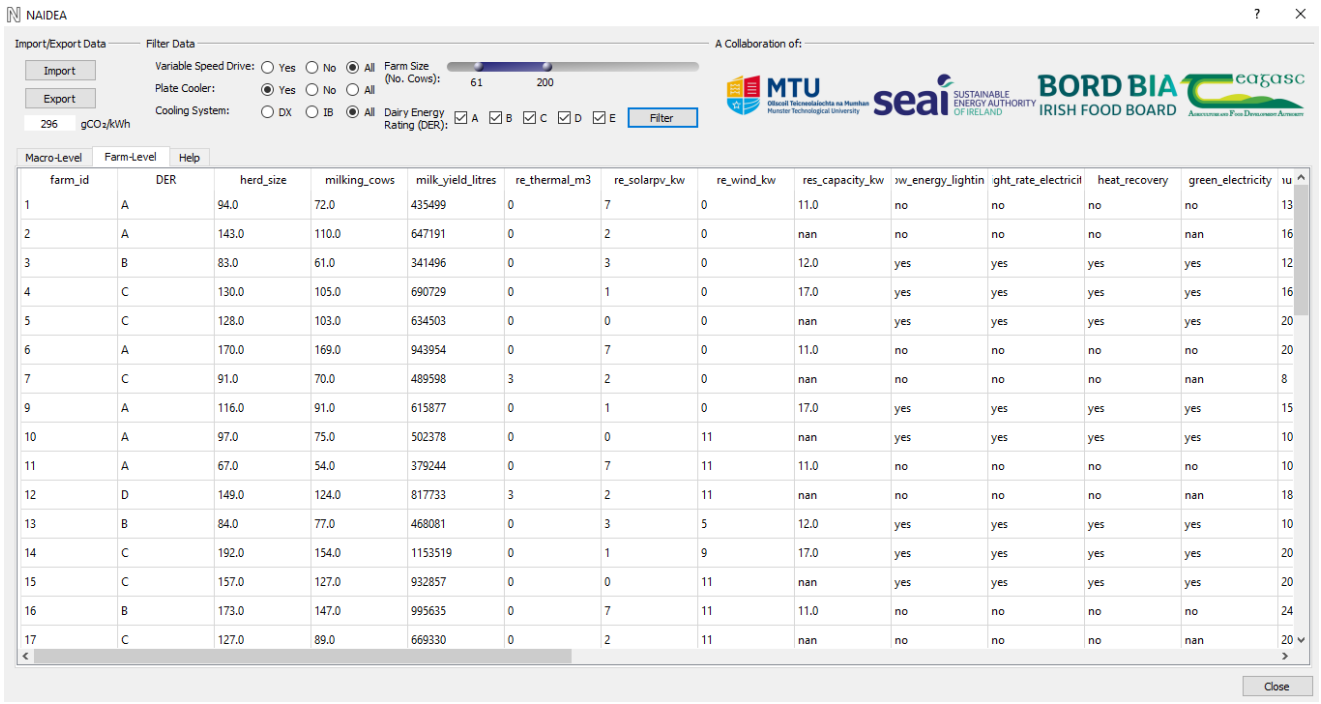


Figure 3 NAIDEA's key performance indicator sub-section

Figure 4 NAIDEA's infrastructural breakdown sub-section

4) A farm-level data section contained the processed dataset (as per selected filter parameters) in tabular form containing all farm-level raw data used to populate charts and figures displayed in the macro-level statistics section. These data include a unique farm identifier, DER, herd size, milk production, capacity of renewable energy generation, etc... The farm-level section can be accessed via label 4 in Figure 1, whereby the GUI is shown in Figure 5.

5) A help section presented a user manual to provide key instructional information to users on how to best utilize NAIDEA. The farm-level section can be accessed via label 5 in Figure 1.



farm_id	DER	herd_size	milking_cows	milk_yield_litres	re_thermal_m3	re_solarpv_kw	re_wind_kw	res_capacity_kw	ow_energy_lightin	ght_rate_electricit	heat_recovery	green_electricity	nu
1	A	94.0	72.0	435499	0	7	0	11.0	no	no	no	no	13
2	A	143.0	110.0	647191	0	2	0	nan	no	no	no	nan	16
3	B	83.0	61.0	341496	0	3	0	12.0	yes	yes	yes	yes	12
4	C	130.0	105.0	690729	0	1	0	17.0	yes	yes	yes	yes	16
5	C	128.0	103.0	634503	0	0	0	nan	yes	yes	yes	yes	20
6	A	170.0	169.0	943954	0	7	0	11.0	no	no	no	no	20
7	C	91.0	70.0	489598	3	2	0	nan	no	no	no	nan	8
9	A	116.0	91.0	615877	0	1	0	17.0	yes	yes	yes	yes	15
10	A	97.0	75.0	502378	0	0	11	nan	yes	yes	yes	yes	10
11	A	67.0	54.0	379244	0	7	11	11.0	no	no	no	no	10
12	D	149.0	124.0	817733	3	2	11	nan	no	no	no	nan	18
13	B	84.0	77.0	468081	0	3	5	12.0	yes	yes	yes	yes	10
14	C	192.0	154.0	1153519	0	1	9	17.0	yes	yes	yes	yes	20
15	C	157.0	127.0	932857	0	0	11	nan	yes	yes	yes	yes	20
16	B	173.0	147.0	995635	0	7	11	11.0	no	no	no	no	24
17	C	127.0	89.0	669330	0	2	11	nan	no	no	no	nan	20

Figure 5 NAIDEA's farm-level section user interface

NAIDEA steps

Step 1. Insert current carbon intensity value. The current default value equals Ireland's 2020 carbon intensity value of 296 kg CO_2 / kWh as reported by SEAI (2021). This value can be updated at any stage by updating the figure and pressing the 'Filter' button.

Step 2. Import Dataset. A full description of dataset and data handling requirements and example dataset is available at: https://doi.org/10.5281/zenodo.6511392. Once a csv file is selected from the file explorer and imported to NAIDEA, all models are called, electricity consumption values calculated and farm-level DERs determined. The length of time this process takes will depend on the size of the imported file. Once finished, the macro-level statistics section will be populated with intuitive charts and the key performance indicator table.

Step 3. Select/deselect filter parameters as appropriate. The default parameters ensure all farms within the imported dataset are selected. Once the user deselects as required, the user can then press the "Filter" button to confirm and re-populate NAIDEA's figures and tables. NAIDEA's filter parameters can be updated and initialized at any time.

Step 4. View generated figures and tables, while toggling through different charts using the radio buttons to the right of each chart, as shown in Figure 3.

Step 5. Download charts as a .png file by hovering the cursor over the required figure and clicking the camera icon, as shown in Figure 6. The camera icon will only display when the cursor is placed on the chart.

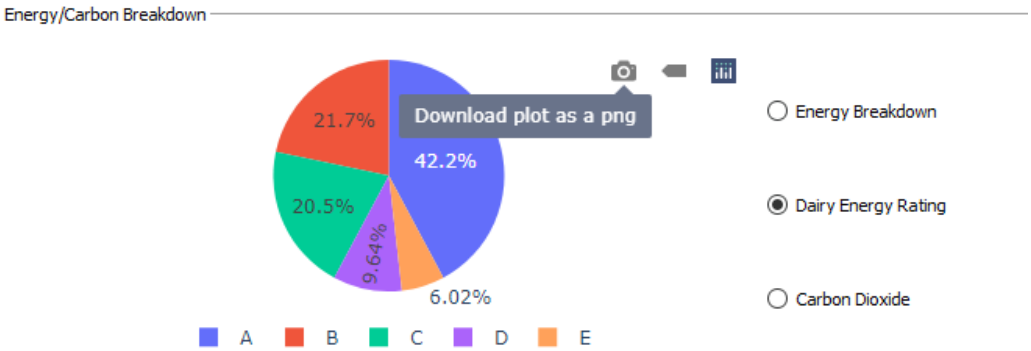


Figure 6 Downloading a figure by clicking the camera icon

Step 6. Export processed database. The processed farm-level data (as displayed in the "farm-level" section (Figure 5) can be exported as a .csv file by clicking the "Export" button in the import/export section (label 1, Figure 1).