IOWA BIOGAS ASSESSMENT MODEL BACKGROUND MATERIAL

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EXECUTIVE SUMMARY

The Iowa Biogas Assessment Model (IBAM) is an economic analysis tool integrated with a geographical information system (GIS). IBAM is available online (www.ecoengineers.us/ibam). This document describes IBAM GIS features and provides definitions for the economic model parameters. This document complements the video tutorials with a summary explanation of IBAM features. IBAM is under active development, and features are subject to change.

IBAM is the product of a collaboration between EcoEngineers and Iowa State University. It was funded by the Iowa Economic Development Authority. Its purpose is to provide users an overview of raw materials available in Iowa for biogas production and the economic potential of producing biogas. IBAM includes maps of potential biogas feedstock sources and details of capital costs for relevant infrastructure. IBAM facilitates the evaluation of the economic potential of harnessing some of these resources at different locations in Iowa.

IBAM provides a preliminary evaluation of a generic biogas facility and is not intended to replace a detailed project analysis. Biogas resource potential and project evaluation is subject to several site-specific constraints, and the model does not guarantee resource quantity/quality or an ROI at any site. The economic estimates are the result of a preliminary and high-level analysis and should not be relied upon for actual business decisions. Users are encouraged to verify the information provided by IBAM by confirming feedstock availability and price with suppliers and by consulting with a qualified project engineering firm on project development costs. The information provided is time-sensitive and may not reflect current resources within the state of Iowa.

The intended audience for the IBAM includes entrepreneurs, policy makers, and the general public. The overall goal of this project is to generate interest inbiogas production by increasing awareness of the availability of feedstock, of federal and state incentive programs and of the economic value of biogas in transportation projects.

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IOWA BIOGAS ASSESSMENT MODEL DOCUMENTATION

The Iowa Biogas Assessment Model (IBAM) consists of two main components: a Geographical Information System (GIS) and an economic analysis tool. The GIS component provides visualization of several types of biogas resources as described below. The economic analysis tool calculates the potential net revenue of a biogas facility based on user assumptions about facility location, size, and costs. These two components are integrated to facilitate rapid comparison of biogas economic potential for different scenarios.

THE IBAM GEOGRAPHICAL INFORMATION SYSTEM

The IBAM interface is shown in Figure 1. IBAM was designed for desktop computers with at least a 1366x768 screen size. It may or may not display or operate properly on phones, tablets, or smaller displays. Most features are tested heavily in Firefox and Chrome, and occasionally in Internet Explorer 9+. The economic tool is anonline excel spreadsheet that can be downloaded by the user. The mapping tooland the spreadsheet are displayed as two separate tabs on the home screen as seen below. The top bar provides links to other IBAM resources including an About page, Tutorials, the Background document, and email Contact.

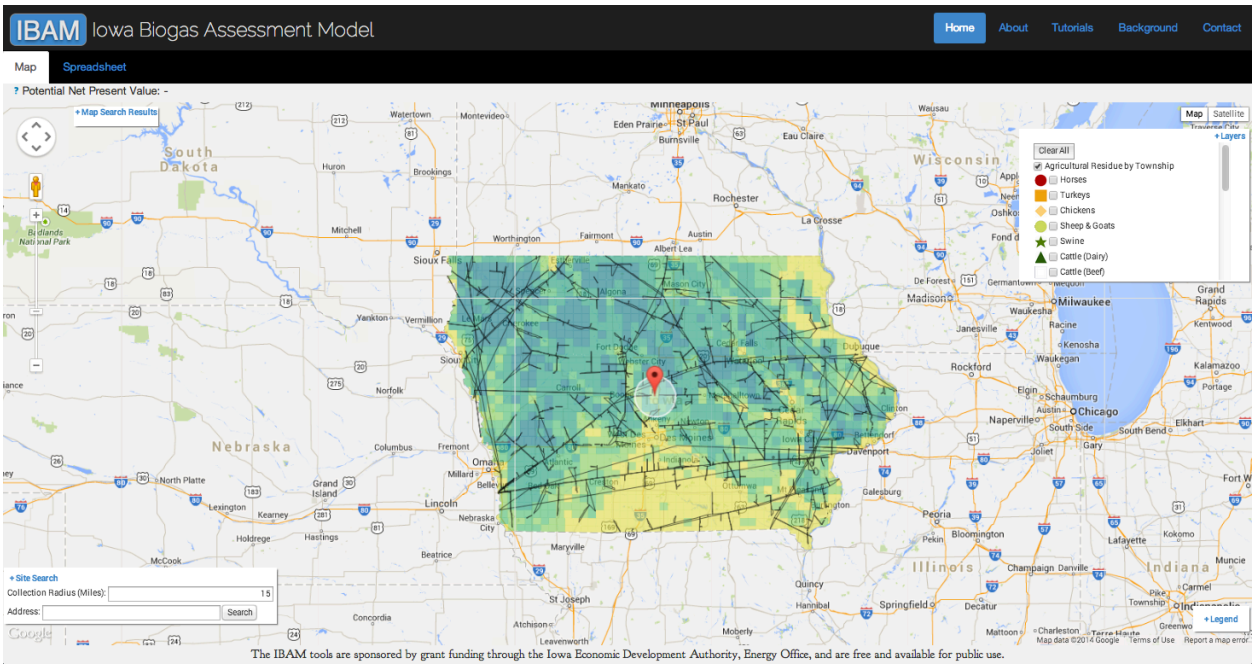

FIGURE 1 IOWA BIOGAS ASSESSMENT MODEL INTERFACE (WWW.ECOENGINEERS.COM/IBAM)

The recommended first step to using IBAM is to configure the map. The map contains features for selecting layers, facility collection radius, and facility location. The IBAM GIS contains more than 20 layers with data for as many types of biogas resources. The current list of layers is given below:

- Agricultural Residue
  - Corn and soybean residue
- Feedlot Waste/Manure
  - Horses

    - Turkeys
    - Chickens
    - Sheep & Goats
    - Swine
    - Cattle (Dairy)
    - Cattle (Beef)
- Human Activity
    - Census Population (2010)
    - Paper Manufacturing Facility
    - Food Manufacturing Facility
    - Biodiesel Plant
    - Ethanol Plant
    - Wastewater Treatment Facility
- Display Layers (not used in analysis)
    - Electric Utility
    - Gas Utility
    - Power Plant
    - Gas Pipeline
    - Landfill Transfer Station
    - Anaerobic Lagoon (DNR)
    - Anaerobic Digester (DNR-Air Quality)
    - Anaerobic Digester (EPA-AgStar)
    - LMOP Site (EPA-LMOPD)

The current list includes layers grouped around common themes. The agriculture residue layer includes the overall corn and soybean residue aggregated to the township level. The feedlot waste/manure layer consists of biogas potential from confined animal facilities. The human activity group represents both human population data and industrial facilities. The display layers group infrastructure and existing digester facilities that could be relevant to a biogas project, but they do not affect the economic calculations. Any combinations of these layers may be selected at a time. However, a large number of layers could decrease browser responsiveness depending on the computing resource available.

The layers include both single-point and spatially distributed data. Single-point layers are shown with using various markers and colors. The marker sizes denote relative biogas potential from the anaerobic digestion of the resource. Multiple markers may overlap in a location if the site has several distinct types of resources. The mapping tool employs a clustering algorithm that combines multiple single-point locations at small zoom levels. This algorithm prevents cluttering the map with hundreds of markers that would otherwise be displayed when viewing the map from a far distance.

Display layers will only add graphical information the map. The information underlying these layers are either not available or not considered in the IBAM model. The criteria for selecting display layers were based on data availability, data quality, and relevance to a potential biogas project.

The mapping tool employs selected layers (not including display layers) for querying biogas potential. Map queries are based on the site location and collection radius. The site location may be chosen by either clicking on the map or by typing an address in the bottom-left search box. The collection radius can

be typed in miles in the same input box group. Map queries will trigger a recalculation of the potential net present value, but an Update button is available in the summary bar for manual recalculations.

IBAM Data Sources:

Agricultural residue from corn and soy crops:

- *Source:* USDA NASS Census of Agriculture, and USDA NASS Cropland Data Layer
- *Edition date:* Residue potential was computed as the 5-year average of data from 2009-2013.
- *Processing:* County-level crop residue potential in bone dry tonnes was computed following the methods of Milbrandt, A. (2005) "*A geographic perspective on the current biomass resource availability in the United States*" United States Department of Energy. Sub-county estimates were derived with dasymetric mapping using agricultural land use data from the Cropland Data Layer, and reaggregation to Public Land Survey System units.

Animal feeding operations:

- *Source*: Iowa DNR Animal Feeding Operations Database
- *Edition date*: January 2014
- *Processing*: Only feeding operations with one or more animals were included in the dataset.

Biodiesel facilities:

- *Source*: Iowa Biodiesel Board, National Renewable Energy Laboratory, National Biodiesel Board, and individual company websites
- *Edition date*: February 2014
- *Processing*: Addresses were geocoded and geographic coordinates manually checked and adjusted based on satellite images.

Cities and towns (Census designated places):

- *Source:* US Census Bureau
- *Edition date:* 2010
- *Processing:* Point representations of census designated places were computed as the geometric centroids of TIGER/Line® place polygons.

Ethanol facilities:

- *Source*: Iowa Renewable Fuels Association, National Renewable Energy Laboratory, and individual company websites
- *Edition date*: February 2014
- *Processing*: Addresses were geocoded and geographic coordinates manually checked and adjusted based on satellite images.

Existing anaerobic digesters and biogas projects:

- *Source:* Iowa DNR Air Quality Construction Permits, Iowa DNR Air Quality Operating Permits, Iowa DNR Animal Feeding Operations Database, Iowa DNR NPDES Wastewater Permits, US EPA AgSTAR, and US EPA LMOP
- *Edition date:* 2014
- *Processing:* Facilities of interest were identified as: facilities with air quality construction or operating permits that contain "digester" or "methanator" in their emission unit description; animal feeding operations with anaerobic lagoons; facilities with a NPDES permit that list "anaerobic digester" as their treatment type; facilities from the EPA AgSTAR database listed as having an operational anaerobic digester; Iowa landfills listed in the EPA LMOP database as "operational", "candidate" or "potential" landfill gas projects.

Food and paper manufacturing facilities:

- *Source:* Manufacturer's News, Inc.
- *Edition date:* April 2014
- *Processing:* Manufacturers that handle food and paper products were identified based on their four-digit SIC codes. Facility addresses were geocoded using the Texas A&M University geocoding service via linear interpolation of street data, parcel matching, or zipcode matching. Some facility locations are approximate.

Group quarter populations:

- *Source*: Iowa Department of Corrections (correctional facility populations), and US Census Bureau (other group quarter populations)
- *Edition date*: FY 2013 (correctional facilities), and 2010 (other group quarter populations)
- *Processing*: Point representations of census designated places were computed as the geometric centroids of TIGER/Line® place polygons. Census group quarter populations were adjusted to eliminate double-counting of correctional facility populations.

Landfills and transfer stations:

- *Source*: Iowa DNR Waste Management
- *Edition date*: FY 2013
- *Processing*: Incoming waste tonnages for landfills were adjusted to eliminate double-counting of waste that was first routed through a transfer station. These adjustments were based on quarterly report data supplied by the DNR.

Municipal electric utilities:

- *Source*: Iowa DNR Geographic Information Systems Library
- *Edition date*: 2007
- *Processing*: None.

Municipal gas utilities:

- *Source*: Iowa DNR Geographic Information Systems Library
- *Edition date*: 2006
- *Processing*: None.

Natural gas pipelines:

- *Source*: Iowa DNR Geographic Information Systems Library, and US Energy Information Administration
- *Edition date*: 2007 (DNR), and 2012 (EIA)
- *Processing*: Natural gas intrastate and interstate pipelines, storage structures, and trunk lines were selected from each source and merged into a non-redundant seamless dataset.

Power plants:

- *Source*: US Energy Information Administration
- *Edition date*: 2013
- *Processing*: None.

Wastewater treatment facilities:

- *Source*: Iowa DNR NPDES Wastewater Permits
- *Edition date:* January 2014
- *Processing*: Only facilities that handle organic/biological materials were included in the dataset. These were identified as having a biological oxygen demand greater than 0.

Special Thanks

- Dr. Michael Schuppenhauer, President, Farmatic Inc.

THE IBAM ECONOMIC MODEL PARAMETERS

IBAM contains a comprehensive list of economic parameters available to accommodate a wide range of potential assumptions related to the cost of operating a biogas facility. Some of these parameter definitions are based on the National Renewable Energy Laboratory's Cost of Renewable Energy Spreadsheet Tool (CREST) and modifications relevant to IBAM.

The default values provided here are placeholders to maintain an operating model and provide a high-level analytical framework. They should not be used to evaluate the feasibility of a specific project. Users are advised to use their own assumptions while creating a project-specific analysis. Economic model parameters are grouped into related sections as follows:

- **Technology selection**: anaerobic digester reactor design selection and costs
- **Plant performance**: facility product configuration and conversion efficiency
- **Capital costs**: display of capital costs calculated from the technology selection
- **Operating costs**: annual operating expenses
- **Financing**: investment structure and rates
- **Tax system**: federal and state income tax rates and structure
- **Revenue sources**: quantities and prices of revenue sources
- **Federal incentives**: structure and rate of federal incentives
- **State incentives**: structure and rate of state incentives
- **Inflation factors**: rates of cost/price increases

Each of the following sections provides a description of the parameters and their default values. Parameter definitions and default values are subject to change. Default values shown here may not reflect the initial values displayed on the IBAM website since these are updated frequently, and browser settings may change parameters to the last entered values by the user.

Some parameters can be modified by either the user or model calculations. Users are referred to the model spreadsheet or website source to follow model calculations. The CREST tool may also provide relevant information to others seeking to replicate the results from the model.

TECHNOLOGY SELECTION

Variable	Default value	Units	Definition
Anaerobic Digester Design:	Custom		Anaerobic digestion tank design (Continuously stirred tank, Plug flow, Covered lagoon, Fixed film) and auxiliary units
Capital Cost	12	$/mmbtu-year	Total project investment
Electrical Conversion Efficiency	0.35		This value indicates the efficiency of biogas conversion into electricity. (Usually 0.30-0.42)
Availability	0.92		This value indicates the percentage of time in which the facility operates. (Usually 0.85-0.95)
Labor, Maintenance, Overhead, and G&A	297900	$/mmbtu-year	Fixed operation and maintenance cost includes: management cost, tax, insurance, land lease and labor cost.
Materials, Chemicals, and Utilities	542000	$/mmbtu-year	Variable operation and maintenance cost includes: materials, chemicals, and utilities.
Biogas Upgrading Capital Cost	8317000	$	Total project investment for raw biogas upgrading equipment per annual biogas capacity
Biogas Upgrading O&M	402000	$/year	Total operating costs for biogas upgrading per annual biogas capacity

PLANT PERFORMANCE

Variable	Default	Units	Definition
Biogas (Raw) Production	167900.0	mmbtu/day	The daily yield of raw biogas. (Before biogas upgrading processes)
Biogas (Raw) Production per Year	56380820	mmbtu/year	The annual yield of raw biogas. (Before biogas upgrading processes)
Pipeline Gas Production	0	mmbtu/year	The annual yield of deliverable biogas. (After biogas upgrading processes)
Biogas Energy Content	550	btu/cubic feet	This value indicates the energy content in biogas. This value may vary depended on methane content. Biogas energy content is usually between 450 to 650 BTU/cubic feet.
Generator Nameplate Capacity	0	kW	This value indicates the intended technical capacity of the generator. (Usually 100-1000kW)
Facility Heat Rate	9748	btu/kWh	This value indicates the amount of heat (BTUs) required in order to generate a certain amount of electricity (kWh). This value represent the power generation efficiency of a facility.
Electrical Conversion Efficiency	0.35		This value indicates the efficiency of the engine converts fuel to electricity. (Usually 30-42)
Waste Heat Capture Efficiency	0.85		This value indicates the efficiency with which waste heat is captured and reused.
Station Service Parasitic Load	0.1		This value indicates the percentage of electricity that consumed by the power plant itself. (Usually 3-17) Total production – Station service parasitic load = electricity which available for sale
Waste Heat Production	0	kWh	This value indicates lost, but recoverable, process heat. It may be sold as a by-product.
Annual Production Degradation	0		This value indicates the drop in plant efficiency due to the natural degradation of the mechanical components. (Usually 0-3)
Facility Availability	0.92		This value indicates the percentage of time per year during which the facility operates. (Usually 85-95)

CAPITAL COST

Variable	Default	Units	Definition
Total Installed Cost before grants		$	The total system cost as calculated by previous assumptions.
Total Installed Cost before grants per mmbtu		$/mmbtu-year	This value represents the total installed cost before grants and the system size.
Total Installed Cost		$/mmbtu-year	This value indicates the total expected all-in project cost. It should include all design, hardware, interconnection, balance of plant, construction, permitting, development cost and interest during the construction.

OPERATING COSTS

Variable	Default	Units	Definition
Feedstock Price	0	$/ton	This value indicates the cost for feedstock. It may include tipping fee or transportation cost.
Feedstock Quantity	0	tons per year	This value indicates the quantity of feedstock purchases per year.
Materials and Utilities	0	$/year	This value is a catch-all for any additional variable costs such as material, chemical, or utility costs.
Labor, Maintenance, Overhead, G&A	300	$/year	This value is a catch-all for any additional fixed costs.
O&M Cost Inflation	0.02		This value indicates the inflation rate for both fixed and variable O&M cost. It also can be applied to insurance and project management cost.
Insurance (of Total Cost)	0.004		This value indicates the cost of insuring the power plant. (Usually 0-2)
Project Management	30000	$/yr.	This value indicates the management cost related to power purchase, grid integration and periodic reporting. (Usually 0-150,000 dollars per year)
Digestate Disposal Costs	0	$/gallon	This value indicates the cost for disposing the solid material remaining of biodegradable feedstock after the anaerobic digestion. (Usually $0.02-0.05) The disposition of this solid remaining can become a source of revenue in some cases.
Digestate Quantity	0	gallons per year	This value indicates the quantity of the solid material remaining of biodegradable feedstock to be disposed of.
Property Tax	0	$/yr.	Also known as PILOT. It includes any local taxes associated with the project.
Land Lease	25000	$/yr.	This value indicates the fixed payments to the landlord for the use of the land.
Royalties of revenue	0		This value indicates the variable payments to site hosts, partners or any other parties which may own a share in this project. Payments covered in “Land Lease” should not be included in Royalties. Inflation is not considered in Royalties of revenue.

FINANCING

CONSTRUCTION FINANCING

Variable	Default	Units	Definition
Construction Period	9	months	This value indicates the number of months from the beginning of construction to the day that the plant is commercially functional.
Interest Rate	0.055		This value indicates the annual interest rate for the construction debt. (Usually 3-10)
Interest During Construction	0	$	This value indicates the interest during the construction period. This value is calculated under the assumption that the total investment is equally spent in each month throughout the construction.

PERMANENT FINANCING

Variable	Default	Units	Definition
Debt of hard costs (mortgage-style amort.)	0.55		This value represents the percentage of debt covering hard costs. Hard costs include equipment and installation costs, but exclude soft costs such as transaction fees, consulting fees, and others.
Debt Term	13	years	This value indicates the number of years in the debt repayment schedule. (Usually 10-20 years)
Interest Rate on Term Debt	0.07		This value indicates the interest rate which provided by debt investor. (Usually 4-10)
Lenders Fee of total borrowing	0.03		Lenders fee is a one-time only fee that collected by the lender. This value usually falls in the range of 1.0-4.0.
Equity hard costs/soft costs also equity funded	0		This value indicates the percentage of total project cost funded by equity investor. This is a calculated value, not an input.
Target After-Tax Equity IRR	0.12		This value indicates the minimum internal rate of return that investors can expect from this project. (Usually 5-20)
Weighted Average Cost of Capital WACC	0		This value indicates cost (after-tax) of equity and debt in proportion to their use.
Other Closing Costs	0	$	This value indicates fees paid at the closing of a transaction, such as attorney fees, title service fees, etc.

TAX SYSTEM

Variable	Default	Units	
Is owner a taxable entity?	Yes		The project owner can be either taxable or non-taxable entity. It determines some tax-related items.
Federal Income Tax Rate	0.35		This value indicates the federal income tax rate.
Federal Tax Benefits used as generated or carried forward?	As Generated		This value indicates whether federal tax benefits are monetized in the same period generated or delayed until the tax liability is equal or greater than the available tax benefit.
State Income Tax Rate	0.085		This value indicates the state income tax rate of the project.
State Tax Benefits used as generated or carried forward?	As Generated		This value indicates whether state tax benefits are monetized in the same period generated or delayed until the tax liability is equal or greater than the available tax benefit.
Effective Income Tax Rate	0		This value indicates the effective income tax rate which is calculated by considering both federal and state tax rates.

REVENUE SOURCES

Variable	Default	Units	Definition
Renewable Identification Number (RIN) Value	1	$/RIN	This value is the monetary credit accrued from the sale of pipeline quality biogas. Each RIN represents 10,000 btus of biogas.
Electricity Price	12.45	¢/kWh	Price of electricity.
Tipping Fee	0	$/ton	This value indicates the fee caused by waste disposal or charge by a waste processing facility.
Quantity (Tipping)	0	tons per year	This value indicates the quantity of material which is subject to tipping fee.
Pipeline Gas Price	5	$/mmbtu	This value indicates the price for pipeline gas.
Digestate Price	0	$/gallon	This value indicates the price for solid remaining after the anaerobic digestion.
Digestate Revenue Escalation Factor	0.01		This value indicates the inflation rate which associates with the digestate price.
Digestate Quantity	0	gallons per year	This value indicates the quantity of

			digestate which need to be disposed.
Waste Heat Available for Sale	0	btu/kWh	Waste Heat Available for Sale = (The heat produced by the generator per kWh – The BTUs used to generate 1 kWh) * heat capture efficiency
Waste Heat Selling Price/Avoided Cost	0	$/btu	This value indicates the selling price of the waste heat.
Waste Heat Selling Price Escalation Factor	0.02		This value indicates the inflation rate which associates with the waste heat selling price.

FEDERAL INCENTIVES

Variable	Default	Units	Definition
Select Form of Federal Incentives	Cost-Based		Federal incentives can be cost-based or performance-based. Cost-based, for example: an investment tax credit. Performance-based, for example: a performance tax credit
Investment Tax Credit (ITC) or Cash Grant?	Cash Grant		This value defines whether the federal incentive is a cash grant or tax credit.
ITC or Cash Grant Percent	0.3		ITC or cash grant as a fraction of the investment cost
ITC or Cash Grant Amount	0	$	Total value of ITC or cash grant
Performance Based Incentive (PBI) Rate	1.15	¢/kWh	Federal incentives for the production of renewable electricity
PBI Duration	10	yrs.	Duration of the PBI. The PBI credit expires after this period.
PBI Escalation Rate	0.02		Rate of increase for the federal PBI
Is PBI Tax-Based PTC or Cash-Based REPI?	Tax Credit		This value defines whether the PBI is awarded as a tax incentive or cash grant
Additional Federal Grants	0	$	Total value of additional Federal grants.
Federal Grants Treated as Taxable Income?	Yes		This value defines whether federal grants are included in tax calculations.

STATE INCENTIVES

Variable	Default	Units	Definition
Select Form of State Incentive	Neither		State incentives can be cost-based or performance-based. Cost-based, for example: an investment tax credit. Performance-based, for example: a performance tax credit
Income Tax Credit (ITC)	0.3		ITC or cash grant as a fraction of the investment cost
Is Performance-Based Incentive (PBI) Tax Credit or Cash Pmt?	Cash Payment		This value defines whether the state incentive is a tax credit or cash grant.
If cash, is state PBI or Renewable Energy Credit (REC) taxable?	No		Total value of ITC or cash grant
PBI or REC Rate	1.5	¢/kWh	Federal incentives for the production of renewable electricity
PBI or REC Payment Duration	10	yrs.	Duration of the PBI. The PBI credit expires after this period.
PBI or REC Escalation Rate	0.02		Rate of increase for the state PBI
Additional State Rebates Grants	0	$/kW	This value defines additional state grants for renewable electricity production.
Total Cap on State Rebates Grants	500000	$	This value is an upper-level ceiling for state incentives
State Grants Treated as Taxable Income?	Yes		This value defines whether federal grants are included in tax calculations.

INFLATION FACTORS

Variable	Default	Units	Definition
Feedstock Expense Escalation Factor	**0.02**		This value indicates the inflation rate associated with the feedstock price.
Digestate Disposal Escalation Factor	0.02		This value indicates the inflation rate associated with the digestate disposal cost.
Water Sewer Expense Escalation Factor	**0.02**		This value indicates the inflation rate associated with the water sewer expense.
Annual Property Tax Adjustment Factor	0		This value indicates the inflation rate associated with the property tax.

RECOMMENDED COMPUTER SPECIFICATIONS

IBAM was designed for desktop computers with at least a 1366x768 screen size. It may not display or operate properly on phones, tablets, or smaller displays. Most features are tested heavily in Firefox and Chrome, and occasionally in Internet Explorer 9+.