

## **DER-VET User Guide**

*User Guide and Technical Documentation for the Distributed Energy  
Resources Value Estimation Tool (DER-VET™)*

**V0.1.1**

---

# **DER-VET User Guide**

*User Guide and Technical Documentation for the Distributed Energy  
Resources Value Estimation Tool (DER-VET™)*

**V0.1.1**

Technical Update, July 2020

EPRI Project Manager  
G. Damato  
A. Maitra

## **DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES**

THIS DOCUMENT WAS PREPARED BY THE ORGANIZATION(S) NAMED BELOW AS AN ACCOUNT OF WORK SPONSORED OR COSPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER EPRI, ANY MEMBER OF EPRI, ANY COSPONSOR, THE ORGANIZATION(S) BELOW, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS DOCUMENT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS DOCUMENT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT.

REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY ITS TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE, DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT, RECOMMENDATION, OR FAVORING BY EPRI.

THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

THE FOLLOWING ORGANIZATION(S), UNDER CONTRACT TO EPRI, CONTRIBUTED TO THIS REPORT:

**XENDEE**

**This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.**

## **NOTE**

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail [askepri@epri.com](mailto:askepri@epri.com).

Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

Copyright © 2020 Electric Power Research Institute, Inc. All rights reserved.

# ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

## Principal Investigators

M. Evans  
E. Giarta  
H. Nathwani  
A. Etringer  
G. Damato  
A. Maitra  
A. Cortes  
R. Ravikumar  
S. Jothibasu  
P.IP

The following organization(s), under contract to the Electric Power Research Institute (EPRI), contributed to this report:

XENDEE  
6540 Lusk Blvd.  
San Diego, CA 92121

This report describes research sponsored by EPRI.

---

This publication is a corporate document that should be cited in the literature in the following manner:

*DER-VET User Guide: User Guide and Technical Documentation for the Distributed Energy Resources Value Estimation Tool (DER-VET™)*. EPRI, Palo Alto, CA: May 2020. V0.1.1.



# ABSTRACT

DER-VET is an open-source, optimization-based planning tool to aid in the design of microgrids and distributed energy resources (DER) deployments to maximize benefit to individual customers, ratepayers, and to society. DER-VET provides a platform to model the operation and subsequent value of a set of DERs (“DER mix”), potentially configured in a microgrid, collectively providing a set of stacked services. DER-VET uses load and other site-specific data to optionally optimize the size of the DERs concurrently with its dispatch optimization. The technologies modeled in DER-VET include various types of energy storage, intermittent renewable generation, fueled generation, controllable loads/electric vehicles, and hybrid resources like combined heat and power (CHP). These energy resources can be used in any combination to improve grid reliability, improve customer resilience by providing backup to local critical loads, decrease the electricity bill incurred by the site, participate in wholesale energy or ancillary services markets, provide demand response or resource adequacy, or some allowable combination of these. DER-VET could be connected with the grid simulation tools (for example OpenDSS™, DRIVE, etc.) to allow for easy transitions between the models.

## Keywords

- Energy Storage
- Valuation
- Dispatch Optimization
- Size optimization
- Cost Benefit Analysis
- Microgrid
- Distributed Energy Resources
- Planning



**Deliverable Number: V0.1.1**

**Product Type: Technical Update**

**Product Title: DER-VET User Guide: User Guide and Technical Documentation for the Distributed Energy Resources Value Estimation Tool (DER-VET™)**

---

**PRIMARY AUDIENCE:** Users of DER-VET

**KEY RESEARCH QUESTION**

How can a user of DER-VET leverage its capabilities to answer their research questions associated with the value streams and business cases distributed energy resources (DERs) can provide towards enhancing customer and community resilience and learn enough about the workings of the software to trust their results?

**RESEARCH OVERVIEW**

DER-VET was developed by expanding on the framework developed in EPRI's Storage Value Estimation Tool (StorageVET). Newfound flexibility from the new platform along with lessons learned from the development of StorageVET allow DER-VET to take on some functionality not possible in StorageVET.

**KEY FINDINGS**

- Takes into account multi-stakeholder perspectives in developing a benefit cost analysis (BCA) methodology for Microgrids and DERs
- Provides a tool for grid planners and technology developers to design and analyze DERs in utility grids and microgrids
- Perform valuation analysis on a set of DERs ("DER mix") in a single use case.
- Co-optimize DER size and stacked service participation.
- Introduce scenario analysis to build confidence in results from a single case.
- Use the scenario analysis features to discover the best site, size, and value for a DER technologies.
- Compare perfect foresight dispatch optimization results to real-world dispatch and learn where value is being missed.
- Provides Qualitative or intangible benefits to facilitate in DER/Microgrid project communication and collaboration
- Provide Quantitative estimates of benefits to assist in decision making for wide range of services: 1) Reliability and Resilience, 2) Energy value, 3) Capacity value, 4) Ancillary service value, and 5) GHG emissions

**WHY THIS MATTERS**

Distributed energy resources, including energy storage, are growing in popularity, owing to their ability to provide local reliability/resilience benefits and recover their cost through a wide array of value streams at all levels of the grid. DERs are characterized by high cost, high uncertainty, but high flexibility. Because of this, it is critical to understand the best ways to locate, size, and

operate DERs. Using a perfect foresight dispatch optimization tool with the sensitivity analysis capabilities of DER-VET can help in the planning phases of a project by enabling rapid analysis of many scenarios with different DER sizes, costs, and value streams. Additionally, DER-VET is valuable as a research tool to inform broad-sweeping analyses of trends in DER value as a function of location, operation, and technical capabilities.

## **HOW TO APPLY RESULTS**

Following applications are supported by DER-VET:

- Locational Screening
- Reliability & Resilience
- DER Design & Operation
- Cost Benefit Analysis
- Co-optimization for Stacked Benefits
- Multi- Perspective Valuation; Utility, 3<sup>rd</sup> Party Developer, Customer
- Sensitivity Analysis

After installing DER-VET, it can be used to determine the upper limit on the value a DER mix could generate, determine the optimal DER sizes to include, and then answer bigger questions through directed scenario analysis.

## **LEARNING AND ENGAGEMENT OPPORTUNITIES**

- DER-VET User-Developer Group

### **EPRI CONTACTS:**

Miles Evans, Engineer/Scientist, [mevans@epri.com](mailto:mevans@epri.com)

Giovanni Damato, Principal Project Manager, [gdamato@epri.com](mailto:gdamato@epri.com)

Arindam Maitra, Senior Technical Executive, [amaitra@epri.com](mailto:amaitra@epri.com)

**PROGRAM:** Program 94: Energy Storage and Distributed Generation

# CONTENTS

<b>ABSTRACT .....</b>	<b>V</b>
<b>EXECUTIVE SUMMARY .....</b>	<b>VII</b>
<b>1 INTRODUCTION .....</b>	<b>1-1</b>
Background .....	1-1
Overview of DER-VET Objectives and Capabilities .....	1-1
DER Project-Specific Cost-Benefit Analysis .....	1-2
Free to Public and Open Source Release .....	1-3
Time-Series Dispatch Optimization .....	1-3
Calculation of Joint or Stacked Services .....	1-4
Size Optimization .....	1-5
Customizable for Location, Sizing, Use Cases .....	1-5
Data Options .....	1-5
Compatibility with Other Tools .....	1-6
<b>2 GETTING STARTED .....</b>	<b>2-1</b>
Download DER-VET .....	2-1
Installing DER-VET (Required for GUI AND Command Line Users) .....	2-1
Extract the DER-VET Environment .....	2-2
Inspect the DER-VET Environment .....	2-4
Install and Bind Optimization Solvers .....	2-5
Confirm Proper Completion of Installation .....	2-5
Updating DER-VET .....	2-7
Installing DER-VET GUI (Not required for command line users) .....	2-8
Prerequisites for DER-VET GUI .....	2-8
Installing DER-VET GUI .....	2-23
Configuring Database for DER-VET GUI .....	2-31
Running DER-VET GUI .....	2-38
<b>3 MODELING APPROACH .....</b>	<b>3-1</b>
Products .....	3-1
Perfect Foresight and Optimization Window .....	3-2
Persistence .....	3-2
Model Predictive Control .....	3-3
User-Defined Control .....	3-3
Operational Planning Horizon .....	3-3
Size Optimization .....	3-3
Multiple-Technology Service Participation .....	3-4
<b>4 SERVICES .....</b>	<b>4-1</b>
Pre-Dispatch Services .....	4-1
Asset Upgrade Deferral .....	4-1

Resource Adequacy.....	4-3
Demand Response .....	4-4
Voltage Support / Power Quality .....	4-6
Backup .....	4-7
Custom User Constraints.....	4-7
Optimization Services .....	4-8
Retail Energy Charge Management .....	4-8
Retail Demand Charge Reduction.....	4-9
Spinning Reserves.....	4-10
Non-Spinning Reserves.....	4-11
Frequency Regulation.....	4-12
Day Ahead and Real Time Energy Market Participation .....	4-14
Valuation Perspectives .....	4-15
Service Compatibility .....	4-16
Value Stacking .....	4-16
<b>5 TECHNOLOGIES .....</b>	<b>5-1</b>
Battery Energy Storage .....	5-1
Solar .....	5-3
Compressed Air Energy Storage (CAES) .....	5-3
Internal Combustion Engine (Diesel, ICE) .....	5-4
<b>6 INPUTS.....</b>	<b>6-1</b>
Model Parameters.....	6-1
Description .....	6-1
Operation .....	6-1
Usage.....	6-3
Time Series Data .....	6-3
Monthly Data.....	6-4
Retail Tariff.....	6-5
<b>7 OUTPUTS.....</b>	<b>7-1</b>
CSV Filesa .....	7-1
adv_monthly_bill file.....	7-1
demand_charges file.....	7-1
dispatch_map file .....	7-1
monthly_data file.....	7-1
npv file.....	7-1
objective_values file.....	7-1
opt_results file.....	7-1
payback file .....	7-1
pro_forma file .....	7-2
simple_monthly_bill file.....	7-2
technology_summary file .....	7-2

timeseries file .....	7-2
DER time series results .....	7-2
value stream columns results .....	7-3
timeseries columns results .....	7-6
cost_benefit file .....	7-6
validation file .....	7-6
Log Files.....	7-6
Error Log .....	7-6
<b>8 REFERENCES .....</b>	<b>8-1</b>
References.....	8-1
<b>A EXPERT INSTALLATION .....</b>	<b>8-1</b>
Download DER-VET .....	8-1
Installing DER-VET (Required for GUI AND Command Line Users).....	8-1
Extract the DER-VET Environment .....	8-1
Inspect the DER-VET Environment.....	8-4
Install and Bind Optimization Solvers.....	8-5
Confirm Proper Completion of Installation .....	8-7
Running DER-VET .....	8-8
Updating DER-VET.....	8-9
DER-VET Community Edition.....	8-10
Prerequisites for DER-VET Community Edition.....	8-10
Installing Internet Information Services .....	8-11
Installing Microsoft SQL Server .....	8-13
Installing SQL Server Management Studio .....	8-18
Configuring the ASP.NET State Server Service .....	8-20
Installing DER-VET Community Edition .....	8-25
Creating the Websites in IIS .....	8-26
Updating the Websites Configurations .....	8-29
Create Log Folder .....	8-33
Configuring Database for DER-VET Community Edition.....	8-37
Running DER-VET Community Edition .....	8-44



# LIST OF FIGURES

Figure 1: Power Reservation Scheme.....	5-2
Figure 2: Hypothetical Actual Power Generation Within Time Step in Response to Power Reservations .....	5-2
Figure 3: Difference in SOE Between Scheduled and Actual Case .....	5-2
Figure 4: Energy Reservations .....	5-3
Figure 5: Example of Model_Parameters_Template_DER.csv .....	6-2





# 1

## INTRODUCTION

### Overview of DER-VET Objectives

DER-VET is an open-source, optimization-based planning tool to aid in the design of distributed energy resource and microgrid deployments to maximize benefit to individual customers, ratepayers, and to society. DER-VET provides a platform to model the operation and subsequent value of a set of DERs (“DER mix”), potentially configured in a microgrid, collectively providing a set of stacked services. DER-VET uses load and other site-specific data to optionally optimize the size of the DERs concurrently with its dispatch optimization. The technologies modeled in DER-VET include various types of energy storage, intermittent renewable generation, fueled generation, controllable loads/electric vehicles, and hybrid resources like combined heat and power (CHP). These energy resources can be used in any combination to improve grid reliability, improve customer resilience by providing backup to local critical loads, decrease the electricity bill incurred by the site, participate in wholesale energy or ancillary services markets, provide demand response or resource adequacy, or some allowable combination of these. DER-VET could be connected with the grid simulation tools (for example OpenDSS™, DRIVE, etc.) to allow for easy transitions between the models.

It is the next generation of EPRI’s energy storage and distributed energy resources (DER) valuation tools. It builds and expands on the functionality, accessibility, and transparency on the success of the previous two iterations of EPRI’s storage valuation tools, the Energy Storage Valuation Tool (ESVT), then the Storage Value Estimation Tool (StorageVET1.0 & 2.0). The tool has been written in the free and increasingly popular Python programming language. As an open-source tool, DER-VET seeks to leverage the culture of community feedback and support of its users and the free-to-use libraries in Python.

### Overview of DER-VET Capabilities

DER-VET is a valuation model for analysis of a broad range of DERs. The tool can be used as a standalone model, or integrated with other power system models, thanks to its open-source Python framework. DER-VET has the following key features:

- A highly detailed representation for many DER technologies, grid, market, and customer services and project specific cost-benefit analysis to communicate multi-perspective financial and economic analysis results
- Free to the public and open source release
- Time-series dispatch optimization simulation
- DER size optimization
- Stacked services
- Ability to customize for location, sizing, use cases
- Compatibility with external databases and other modeling tools
- Co-optimized DER portfolio sizing to address microgrid reliability and customer resilience

- Offers flexible optimization horizon & offers simulation time-step granularity (utilize hourly and sub-hourly data for various applications)
- Quantify storage state of health by utilizing different degradation models
- Offers web and desktop-based user interface

### ***DER Project-Specific Cost-Benefit Analysis***

The fundamental use of DER-VET is to understand DER or microgrid project economics and operations. The tool is adaptable to many settings, including research, policy or regulatory analysis, commercial decisions (by a range of actors), infrastructure planning and research. DER-VET incorporates realistic financial pro forma outputs which support analysis of project finance. With respect to benefits, it can calculate optimal market revenues or avoided costs associated with alternative infrastructure or resources. Salient features include:

- *Multi-perspective value stream*: DER-VET can analyze many variations on DER value streams across a range of applications.
- *DER Ownership models*: DER-VET can analyze different ownership models (utility, customer, 3<sup>rd</sup> party, PPA)
- *Cost Benefit Analysis (CBA) Metrics*: DER-VET can automatically calculate key cost-benefit analysis outcomes. Some of the metrics could include: Project Net Present Value (NPV), Benefit-to-cost ratio, return on investment, avoided cost breakdowns based on value streams, cost of covering critical load
- *Value of resilience/Value of Supply*: DER-VET allows the flexibility to include the direct costs of high impact low frequency outages to customers
- *Tax calculations*: DER-VET can calculate federal, state and property taxes and potential tax deductions due to FITC qualification
- *Additional Incentives*: DER-VET has a functionality to include other external incentives as defined by the user in the financial calculations.

<ul style="list-style-type: none"> <li>▪ <b>Multi-Perspective Value Streams:</b> <ul style="list-style-type: none"> <li>• Customer bill reduction</li> <li>• Market participation</li> <li>• Reliability/Resilience Value of Service</li> </ul> </li> <li>▪ <i>Output:</i> Cost/benefit components and avoided costs</li> </ul>	<ul style="list-style-type: none"> <li>▪ <b>DER Ownership Models:</b> <ul style="list-style-type: none"> <li>- Utility</li> <li>- Customer</li> <li>- 3<sup>rd</sup> Party</li> <li>- PPA</li> </ul> </li> <li>▪ <i>Output:</i> <ul style="list-style-type: none"> <li>- CBA results with different perspectives</li> <li>- Value stream validation</li> <li>- Stacked services</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ <b>CBA Metrics &amp; Value of Supply:</b> <p>Have DER-VET automatically calculate key cost-benefit analysis outcomes (not always applicable in cases with different asset lifetimes)</p> <ul style="list-style-type: none"> <li>- Basecase comparison</li> </ul> </li> <li>▪ <i>Output:</i> <ul style="list-style-type: none"> <li>- Project net present value</li> <li>- Benefit to cost ratio</li> <li>- Return on investment</li> <li>- Breakeven cost</li> <li>- Cost of covering critical load</li> </ul> </li> </ul>
---	--	---

**Figure 1-1. Microgrid Design Variations, Economic Optimization, and Stacked Benefits Considerations within DER-VET**

### ***Free to Public and Open Source Release***

The full source code will be made available to anyone for free on [www.der-vet.com](http://www.der-vet.com) along with supporting files and example cases. The tool, once downloaded, can be installed and executed on any computer, eliminating the necessity to upload potentially sensitive information to a cloud-based solution.

### ***Time-Series Dispatch Optimization***

DER-VET calculates the optimal operation for DERs, within a default or user-specified environment. This means that the economic results returned by DER-VET represent the best-case scenario while still respecting the technical limitations imposed by the user.

In some DER applications, as in generating or shifting energy on a well-defined tariff or PPA structure, the dispatch optimization will yield results that represent real cases very well. In other applications, such as demand charge reduction or transmission/distribution asset upgrade deferral, the optimized results represent a more aggressive, risk-tolerant control strategy than would be implemented in a real case. This is because the perfect foresight dispatch optimization has perfect knowledge of what will be required of the DERs in the future to meet a demand reduction or peak shaving target and can fully-utilize the remaining capabilities of the DERs for economic benefit. This is very relevant when technologies have a persistent state (e.g. the SOC for energy storage, demand response, electric vehicles), which links all points in time together.

The dispatch optimization incorporates time-series data on customer and system electric loads and energy and ancillary service prices in either hourly, 15-minute, 10-minute, or 5-minute resolution. In addition to many technical parameters of the DER mix, it also incorporates certain time-dependent variables for technologies with a persistent state, notably tracking of storage systems' or electric vehicles' state of charge (SOC). Because the storage system's SOC couples

every moment in time (actions now impact the capabilities of the system in the future), a time-series dispatch optimization is required instead of an independent, quasi-steady state analysis, like is often done for other technologies.

Due to the need to process many cases in short order and the desire to achieve provably-optimal results where possible, a linear optimization was developed for optimal scheduling of storage dispatch. However, in order to yield more sensible results and avoid physical infeasibilities, the mixed integer linear programming formulation is implemented by default. This formulation yields very good results but can result in prohibitively-long solve times, especially when high-resolution data is used to optimally size many DERs. To balance this, the DER-VET user is warned when a particularly-large case is about to be run and other methods are presented to answer the same questions without the need for a large optimization problem.

### ***Calculation of Joint or Stacked Services***

DERs can be connected in four domains in DER-VET: a generator, the transmission system, the distribution system, and on the customer side of the meter. Depending on the location, and applicable regulatory or market rules, DERs can offer a wide range of services to a range of actors, include those related to PPA structures, the wholesale markets, distribution planning and operations, customer tariffs, and other programs. When DERs can provide these services jointly, the resulting values from each service are “stacked” on each other to achieve the total value. In these calculations, it is critical not to double count the capabilities of the DER mix. When the user selects services for analysis, DER-VET evaluates the compatibility of services along with the capabilities of the DERs when developing the stacked service valuation.

To understand how service stacking is handled in DER-VET, it is important to understand the difference between an optimization service and a constraint service. An optimization service does not have hard requirements – the DER mix is free to operate in a way that generates the maximum economic benefit with no constraints apart from those that ensure the result is feasible and sensible. A constraint service is a service relating to reliability, which defines bounds on the state of the system. For example, a distribution asset upgrade deferral may require that the DERs generate/discharge power to keep the power level in a distribution asset below a threshold. There is nothing to optimize here – just a hard dispatch requirement. If the DER mix is providing other services, it can do so to the best of its ability as long as it meets the deferral constraint.

Service compatibility has a few key dimensions to consider, including:

- **Location-Related**

Certain services are only accessible at certain locations. For example, customer bill savings services require a project location behind the customer meter. Distribution or customer connected systems may be able to sell wholesale services but only after reservation of DER capacity needed for distribution services. DER-VET respects all such limitations and can also be used to evaluate combinations of applications which may be physically feasible but not allowed under current market or regulatory rules.

- **Time-Related**

Due to the potential for multiple services, some of which require concurrent operations and others which do not, DER-VET can aggregate constraints and compile them into power and energy reservations or constraints at the point of interconnection. These constraints ensure

that the DER mix can feasibly provide the concurrent services (i.e. a service that requires discharging is not concurrent with a service that requires charging) and that providing one service now does not preclude another constraint service in the future (i.e. a storage system will maintain an acceptable SOC for future applications).

- **Prioritization in Selection Among Services**

In many applications, the storage device will provide certain services which have a priority over other services. For example, the system operator may want to ensure that the device is available for discharging during peak load periods (as a resource adequacy capacity resource) regardless of what energy market prices are in those periods. Similarly, for a device providing distribution deferral or customer retail rate management, there may be residual opportunities for providing wholesale services which cannot violate the primary uses. There are many such possibilities. DER-VET does not prioritize one service over another – if two constraint services conflict, DER-VET will not run.

### ***Size Optimization***

DER-VET can include DER size parameters directly in the same optimization problem that solves stacked service participation. The result of the size optimization is the co-optimized size and operation of all DERs considered in the analysis given their costs and capabilities. While this increases the computational intensity of the optimization problem, it can give a good starting point for continued exploration using scenario analysis and more detailed assumptions.

### ***Customizable for Location, Sizing, Use Cases***

DER-VET allows the user to conduct sensitivity analysis on many input parameters, including location, size, and applications. DER-VET can be used to optimally size DERs at a large number of locations and then compare the financial and operational results between cases. DER-VET can capture the expected service value based on a range of inputs that are either optimization driven or constraint-based services.

### ***Data Options***

DER-VET includes a small amount of pre-loaded data and users can upload their own data, if it is first converted to the appropriate format. The pre-loaded data includes hourly and sub-hourly wholesale historical California Independent System Operator (CAISO) market prices at a zonal level and load information sourced from the CAISO. It also includes a few example tariff structures for retail customers which have the potential to benefit from energy storage, particularly those with significant demand charges or time-of-use (TOU) energy rates. The data sets include illustrative load shapes for customers and distribution loads.

The pre-loaded data is accurate and useful for illustrative purposes, but generally is not sufficient to evaluate projects located at one of the over 3000 CAISO energy pricing nodes or specific distribution level applications. So, DER-VET is built with the capability to connect to external data sources. These include, the CAISO OASIS data download API, NREL's PVWatts API, the OpenEI tariff database, and others.

Finally, cost and performance information is provided by EPRI from recent cost studies to provide default characteristics ([EPRI 3002008877](https://www.epri.com/~/media/2324/1/EPRI_3002008877.pdf)). ESIC provides templates for supporting the

collection of data related to energy storage cost and specification. Latest versions can be found at [www.epri.com/esic](http://www.epri.com/esic) .

### **Compatibility with Other Tools**

DER-VET can interface with other modeling tools that complement its capabilities and offer a more complete picture of DER benefits, costs, objectives, technical operations, and constraints. It is currently being used to interface the tool with distribution-level power flow modeling and production cost modeling tools..

When interfacing with distribution power flow modeling tools, the specific analytical process could be:

1. The power flow model is used to characterize locational and time-varying constraints on the distribution feeder relevant to DER operations (primary service),
2. Those constraints are then incorporated into DER-VET optimization to evaluate stacked benefits opportunities,
3. The resulting DER dispatch from DER-VET is incorporated back into the power flow model to validate if the DER operational schedules for secondary applications does not create negative impact and that there are no second-order violations. Also, this may enable evaluating other performance evaluations such as asset loading, distribution-related energy losses, and asset degradation.

When interfacing with production cost modeling (PCM) tools, there are several variations. First, production cost models are typically used to 1) Understand the change in production costs, revenue streams, and steady-state reliability impacts with potential changes in system operating procedures or market design, e.g., introduction of new services (fast frequency response, flexible ramp products) or scheduling processes, state of charge management options, etc. 2) Determine potential revenue streams, system operations, emissions, aggregate production costs and hourly marginal prices for certain market services in a future time year or set of years. The resulting hourly prices can then be used in DER-VET to understand potential revenue streams of a storage technology or compare project options on a near-term future time frame across a range of applications. As price taker model, following assumption apply: ) the storage resource does not significantly impact the marginal cost/price of energy and/or the service (e.g., regulation reserve, spinning reserve) that is being assessed, and 2) that the marginal costs that are being used as input are representative of the scenario that is being reviewed

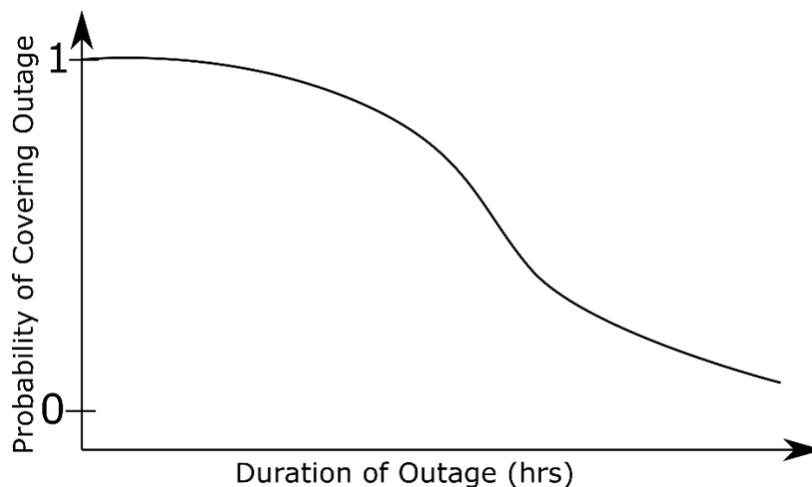
Second, DER-VET can offer to ability to quickly and easily run multiple sensitivities with *trusted* price data to determine advantages for different power/energy sizing dimensions and state of health implications. DER-VET can also provide financial results such as Pro Forma and Net Present Value with *trusted* price data over a sufficiently lengthy time period. Another example is that PCM typically have an internal storage technology representation which does not incorporate as many constraints as DER-VET. In these types of uses, DER-VET could similarly be used to clarify the likely dispatch by the storage device and returned to the production cost model.

In addition, DER-VET could interface with many other types of models or tools. In all these joint model applications, the uses of DER-VET will evolve over time. EPRI will make available additional methodological details as they are available.

### ***Co-optimized DER portfolio sizing to address microgrid reliability and customer resilience***

In the past, reliability and resilience were handled in StorageVET and many other tools by simply reserving some energy capability (stored energy in a storage system or generator, etc.) that would not be used by economic services. DER-VET will have more detailed analysis capabilities, expanding the reliability service to include dynamic, time-varying energy reservations, size constraints, and reconfigurability. This capability will allow the user to specify a desired level of reliability and have the tool automatically ensure the DERs are sized and operated to meet that level of reliability. Additionally, the tool can handle reliability as a post-optimization calculation. This treats reliability as a positive side-effect of the DERs and the other services they provide instead of optimizing for reliability directly.

While reliability has a set of well-defined metrics that can meter reliability and how much it is improved with the presence of DERs, resilience is often considered less well-defined. However, they both have to do with the ability of a microgrid to supply power to (critical) loads at all times. In many cases, reliability metrics exclude extreme events that need to be considered for resilience. For these reasons, DER-VET adopts the (critical) load coverage probability approach in its handling of reliability and resilience. Only the probability of the DERs having enough energy and power capability to cover a grid outage of a specified duration is important in DER-VET and SAIDI, SAIFI, CAIDI, etc. are not used to specify reliability outcomes.



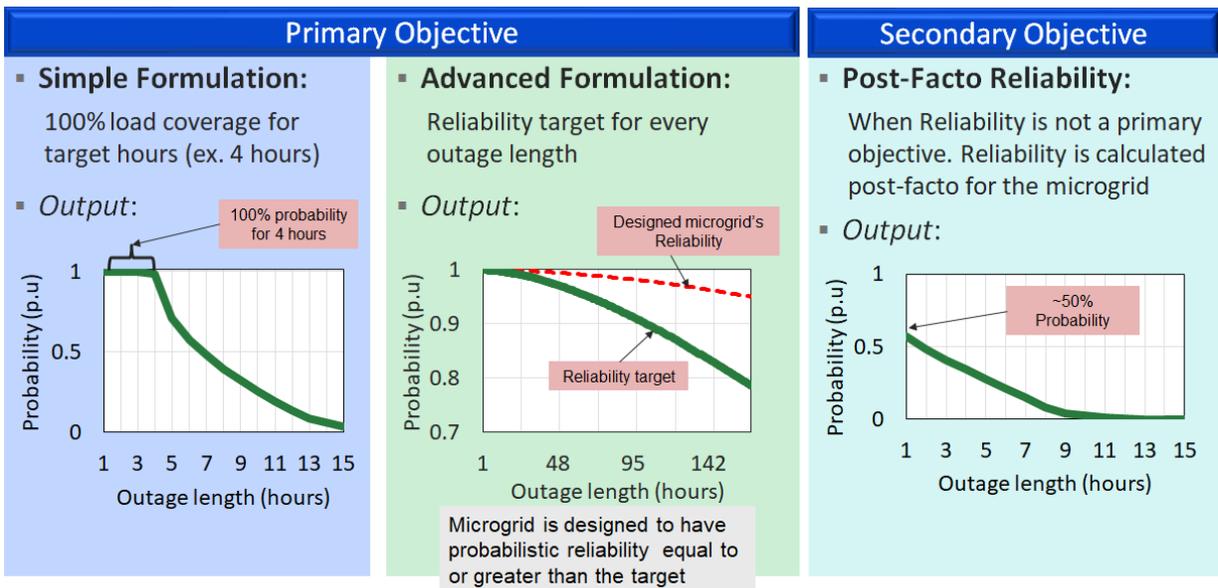
**Figure 1-2: Example Critical Load Coverage Probability Curve (to be met or exceeded for all durations)**

The critical load coverage probability curve is generated by considering every possible outage of each specified duration and determining if the DER mix is capable of covering that outage. The probability of covering an outage of a given duration is the fraction of these hypothetical outages the DER mix could cover, which implicitly assumes that the probability of an outage occurring is equal at all time steps. Additionally, for technologies that have a state (e.g. storage), the operation of these technologies will be constrained such that, along with the other DERs, the

DER mix will be capable of meeting or exceeding the coverage probability requirement. When doing size optimization, the operational power and state of energy constraints imposed by this service will by proxy constrain the size of the DERs so they can meet the reliability objective.

Customer reliability and resilience is measured in terms of the ability of a microgrid to serve critical load during an outage. DER sizing based on reliability and resiliency metric can be achieved using following two approaches in DER-VET.

1. The first approach sizes DER portfolio to always serve critical load (100% probability) for a user-input target outage length ‘t’. All possible outage scenarios of length ‘t’ within given load profile are considered in this analysis. This approach is included as linear optimization constraint in DER-VET formulation. It is relatively simple compared to the second approach.
2. The second approach incorporates all practical assumptions in reliability calculation. It considers all possible outage lengths, solar intra-hourly variation and equipment failure probability (future implementation). Reliability of a microgrid is calculated as a percentage of outage scenarios that the microgrid can successfully serve to total scenarios analyzed. Output of this calculation is probability of serving critical load (%) for every outage length. This detailed probabilistic reliability calculation is not included as a part of the optimization module but added as a post-facto calculation, outside the optimization module. DER sizing using this approach can be done by following methods based on reliability target:
  - If there is no reliability target, microgrid can be sized for some other economic objective and reliability of the designed microgrid can be evaluated as a post-facto calculation.
  - If there is a reliability target, then DER-VET can be iteratively called by an external script to meet the reliability target of the desired microgrid.

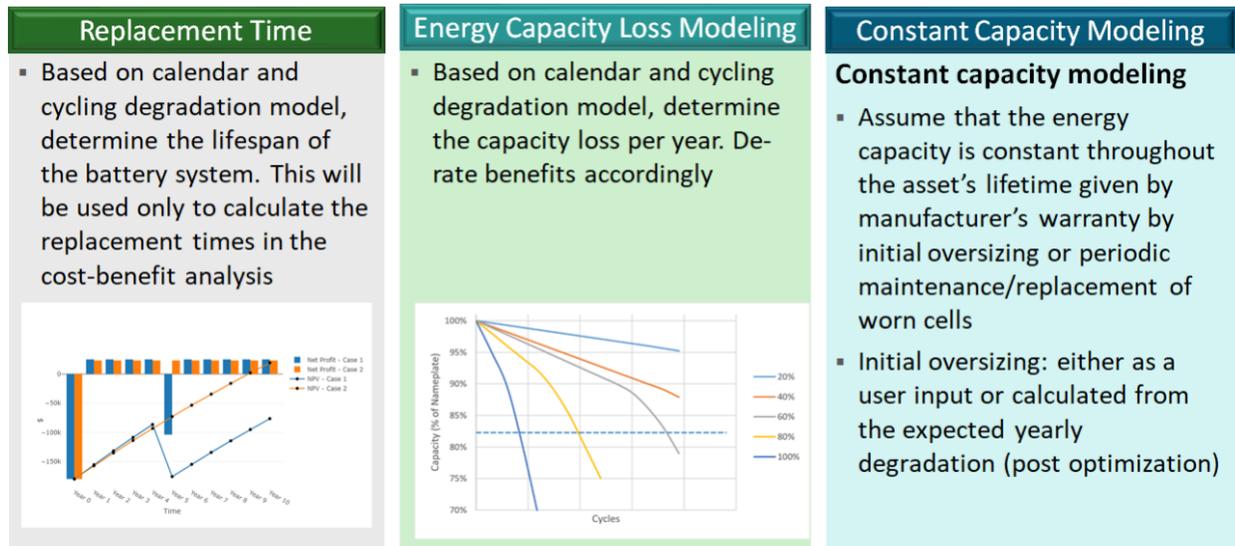


**Figure 1-3. Customer Reliability Options Considered within DER-VET**

## Degradation

Li-ion storage degradation is driven by temperature, cycling, average SOC, among others. The main effect of degradation is loss of energy capacity. It leads to different questions around storage projects:

- Should one oversize the system? Or it is better to operate with lower-capacity systems
- What type of warranty does the vendor provide?
- Is there an operational requirement for warranty?
- How are costs transferred to the owner?



**Figure 1-4. Storage Degradation Modeling Approaches**

Degradation is quantified as the sum of cycling degradation and calendar degradation. Calendar degradation is the yearly degradation that an idle battery system would undergo, and it's parameterized by a customer input that corresponds to the expected idle lifespan of the battery. Cycling degradation comes from counting SOC cycles and is parameterized by a Lifespan vs depth of discharge curve. This curve maps different depths of discharge to battery lifespan in cycles. This model can represent a battery system in which the operator takes the degradation risk, but also can represent the case in which the risk is assumed by the vendor (warranty-like)

## Services

Services in DER-VET are activities the DER mix can do to generate value. Services are broken into two categories – “pre-dispatch (constrained) services” and “optimization services”. Pre-dispatch services require fixed contributions of power and energy from the DERs to achieve. They are called “pre-dispatch” services because they are treated as constraints in the optimization problem, so are effectively modeled before the operation of the DERs are known. Services relating to reliability or safety are usually in this category. “Optimization services” are those where the economic value of the service and the amount the DERs participate are flexible and ultimately determined by the optimization problem. These services are usually economic in nature, like customer bill reduction services or wholesale market participation.

### ***Pre-Dispatch Services***

The pre-dispatch services in DER-VET are used to model some scenario features that introduce some operational requirements that must be satisfied. Before the optimization occurs, a compatibility check is performed on the constraints that model pre-dispatch services to guarantee no infeasibility due to contradictory constraints. If conflicts occur, the user is notified of the infeasibility and the analysis halts.

The following sections elaborate on the pre-dispatch services within DER-VET

- Asset Upgrade Deferral
- Resource Adequacy (Not in Beta)
- Demand Response (Not in Beta)
- Voltage Support / Power Quality (Not in Beta)
- Reliability/resilience
- Custom User Constraints

### ***Optimization Services***

The dispatch optimization takes as inputs the DER mix's technical parameters, operating constraints, prices for ISO market services, and tariff rates if the system is located behind the meter, to produce an operational profile that maximizes the combined service value. The operation revenue optimization is formulated as a mixed integer linear optimization problem.

The following sections elaborate on the dispatch services within DER-VET:

- Retail Energy Time Shift
- Retail Demand Charge Reduction
- Spinning Reserves
- Non-spinning Reserves
- Frequency Regulation
- Day Ahead Energy Time Shift
- Load Following

### ***DER Technologies***

Following DER technologies are considered

- Internal Combustion Engine Generator
- Battery Energy Storage
- Compressed Air Energy Storage
- Uncontrollable Renewable Generation
- Thermal Storage
- Thermal Electric Storage
- Flexible Load

- Electric Vehicles
- Combined Heat and Power
- Combustion Turbine
- Energy Efficiency
- Pumped-Storage Hydropower

# 2

## GETTING STARTED

### Download DER-VET

DER-VET is available for download at <https://der-vet.com/>. Complete the brief Survey Monkey form called 'DER-VET Beta Tester Sign Up'. After completion, click the link to download the zipped standalone DER-VET environment for version 0.1.1: `dervet_v011.zip`.

**Download DER-VET**

- DER-VET Standalone Environment  
(use the form below)
- License

Requirements for running DER-VET Community Edition:

- Microsoft Windows Operating System
- Internet Information Services (IIS)
- Microsoft SQL Server

**EPRI** | ELECTRIC POWER RESEARCH INSTITUTE

**DER-VET Beta Tester Sign Up**

\* 1. Email Address (We will send you the feedback form here)

\* 2. Name

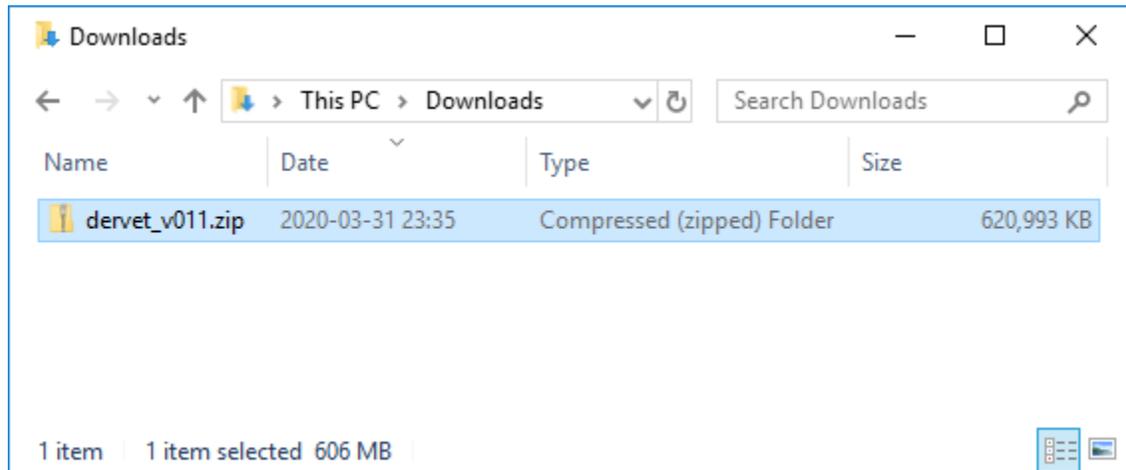
powered by SurveyMonkey

### Installing DER-VET (Required for GUI AND Command Line Users)

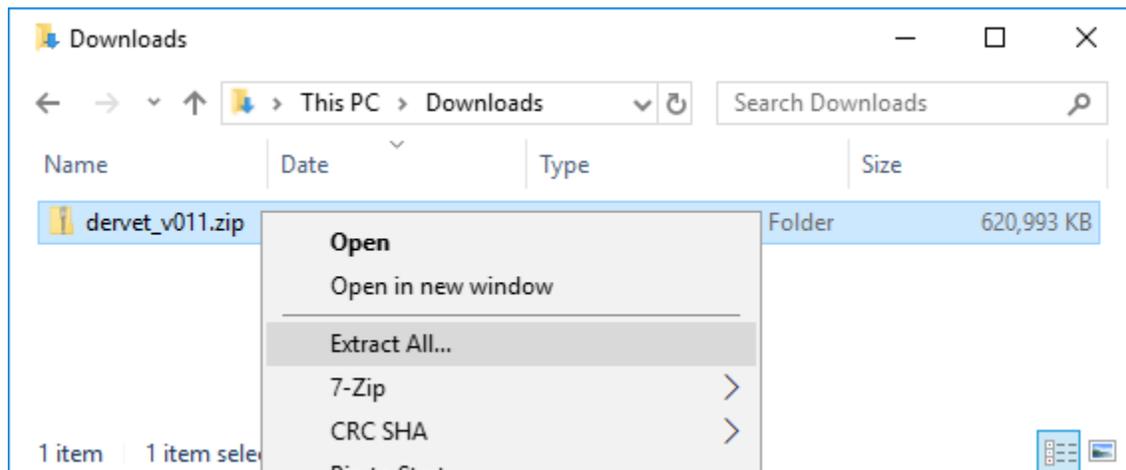
DER-VET can be used in two ways – from the command line and with a graphic user interface (GUI). Using the GUI requires installing the command line version of DER-VET first.

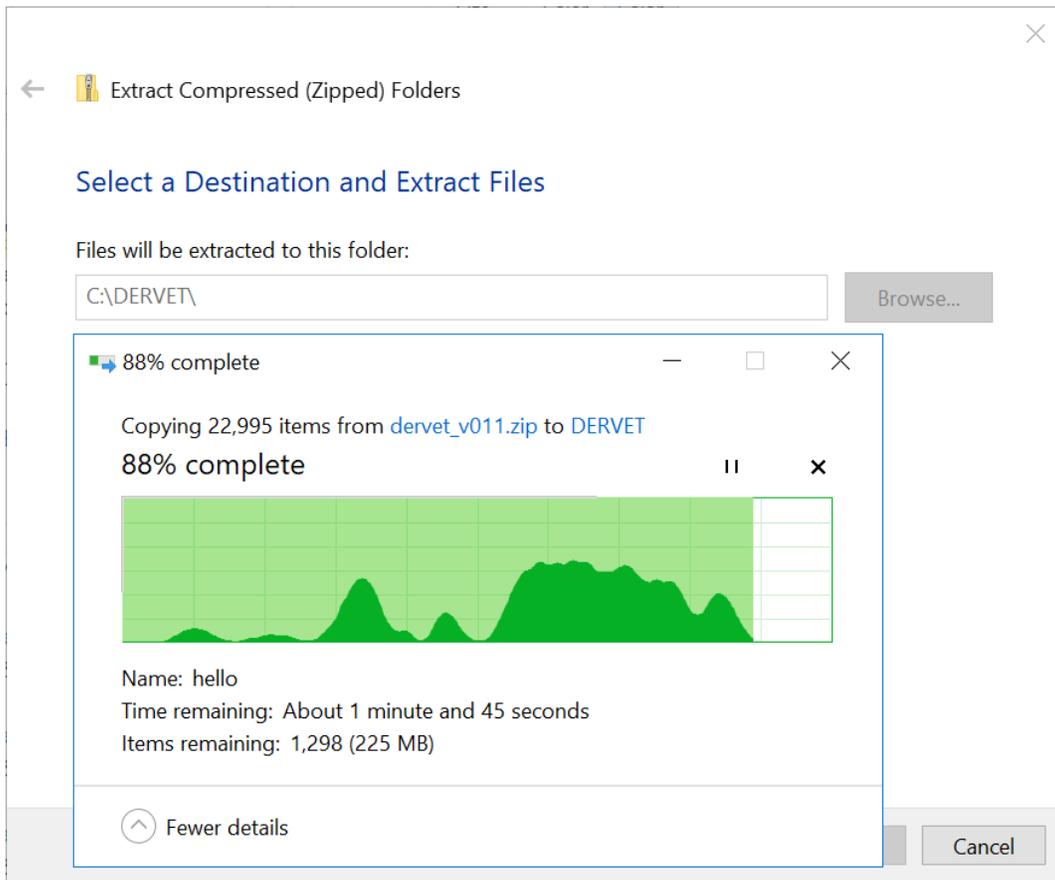
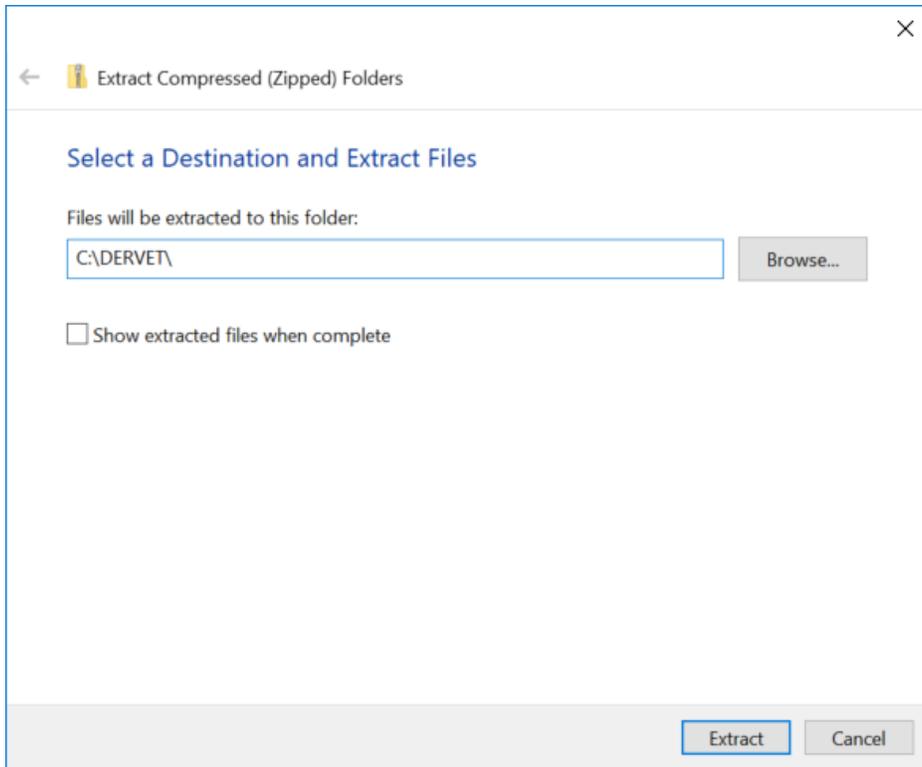
## Extract the DER-VET Environment

1. Download the zipped DER-VET environment.



2. Unzip the environment precisely to the following location on your computer.
  - a. C:\DERVET\
  - b. This may take a few minutes, due to the number of files in the zipped folder.

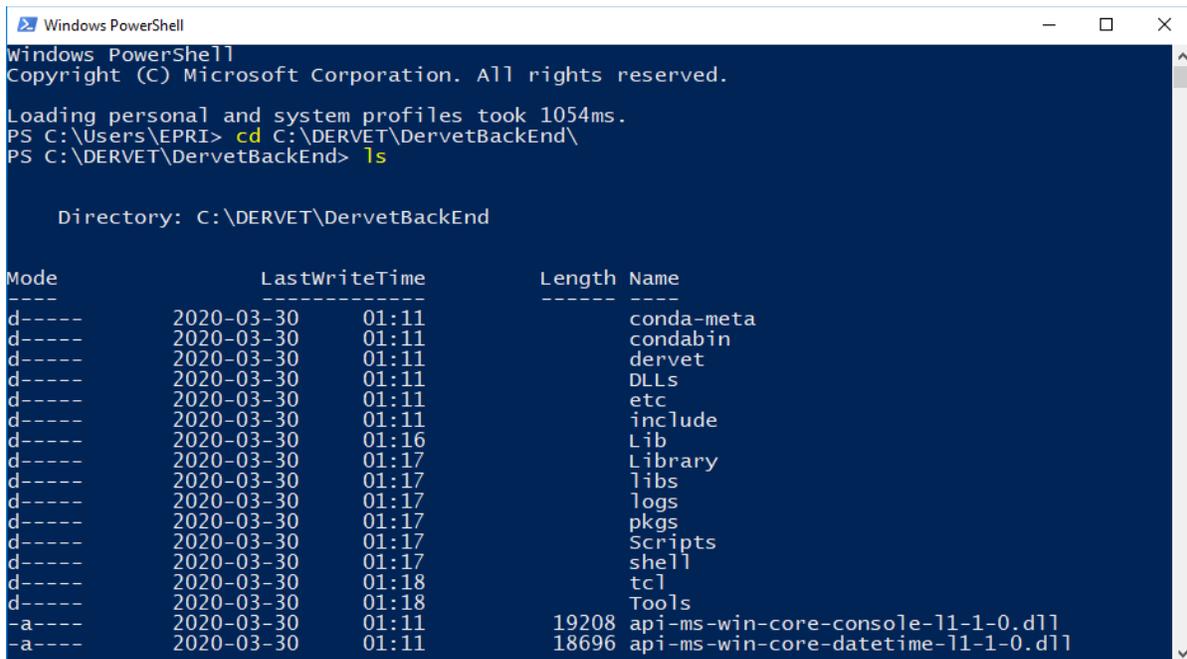




c. This may take a few minutes, due to the number of files in the zipped folder.

### ***Inspect the DER-VET Environment***

3. Open a terminal window.
  - a. Windows Powershell is recommended for the following steps.
4. Navigate into the unzipped Python environment. This is the working directory for DER-VET.
  - a. `> cd C:\DERVET\DervetBackEnd\`



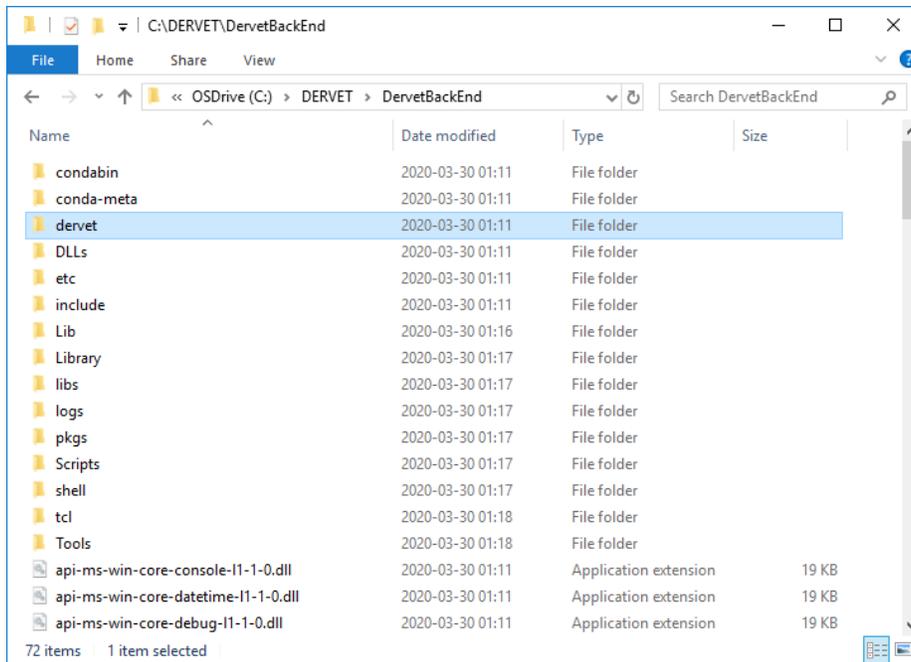
```
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Loading personal and system profiles took 1054ms.
PS C:\Users\EPRI> cd C:\DERVET\DervetBackEnd\
PS C:\DERVET\DervetBackEnd> ls

Directory: C:\DERVET\DervetBackEnd

Mode                LastWriteTime         Length Name
----                -
d-----          2020-03-30 01:11          conda-meta
d-----          2020-03-30 01:11          condabin
d-----          2020-03-30 01:11          dervet
d-----          2020-03-30 01:11          DLLs
d-----          2020-03-30 01:11          etc
d-----          2020-03-30 01:11          include
d-----          2020-03-30 01:16          Lib
d-----          2020-03-30 01:17          Library
d-----          2020-03-30 01:17          libs
d-----          2020-03-30 01:17          logs
d-----          2020-03-30 01:17          pkgs
d-----          2020-03-30 01:17          Scripts
d-----          2020-03-30 01:17          shell
d-----          2020-03-30 01:18          tcl
d-----          2020-03-30 01:18          Tools
-a-----          2020-03-30 01:11        19208 api-ms-win-core-console-l1-1-0.dll
-a-----          2020-03-30 01:11        18696 api-ms-win-core-datetime-l1-1-0.dll
```

- b. C:\DERVET\DervetBackEnd should include the following folders and files:
  - i. Scripts\
  - ii. dervet\
  - iii. python.exe
  - iv. LICENSE\_PYTHON.txt



c. Check the contents of the folder with Windows Explorer or use the `ls` command in Powershell.

i. `> ls`

### ***Install and Bind Optimization Solvers***

5. Execute the following 5 lines in Powershell:

```
C:\DERVET\DervetBackEnd\Scripts\conda.exe install --yes -c conda-forge glpk
```

```
$env:CVXOPT_BUILD_GLPK=1
```

```
$env:CVXOPT_GLPK_LIB_DIR="C:\DERVET\DervetBackEnd\Library\lib"
```

```
$env:CVXOPT_GLPK_INC_DIR="C:\DERVET\DervetBackEnd\Library\include"
```

```
C:\DERVET\DervetBackEnd\Scripts\pip.exe install cvxopt
```

### ***Confirm Proper Completion of Installation***

Run the default case in DER-VET. To confirm proper installation of the environment. The default case is a solar plus storage deployment performing customer side of the meter retail energy time shift and demand charge reduction.

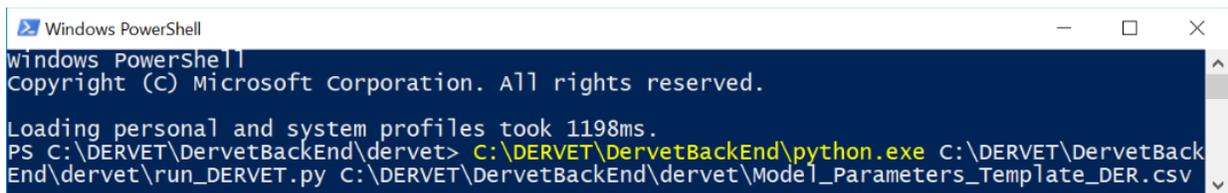
6. Locate the DER-VET folder named `dervet` in your working directory.

7. Navigate into the `dervet` folder with your command prompt.

8. This should contain folders and files such as:

a. `Data\`

- b. Results\
  - c. run\_DERVET.py
  - d. Model\_Parameters\_Template\_DER.csv
9. In Powershell command line or a normal command prompt, enter the following to run the default DER-VET case:
- a. Copy the full file path to the version of python that is included in DER-VET and paste it into your open command prompt followed by a space.
  - b. Enter the full path to your run\_DERVET.py script without the quotation marks into your command prompt, followed by a space.
  - c. Enter the full path to your Model\_Parameters\_Template.csv file into your open command prompt and then press enter.
  - d. The full command should look like:
- > C:\DERVET\DervetBackEnd\python.exe  
 C:\DERVET\DervetBackEnd\dervet\run\_DERVET.py  
 C:\DERVET\DervetBackEnd\dervet\Model\_Parameters\_Template\_DER.csv



10. If your installation worked, the tool should run produce results in the .\Results folder.
- a. You may see the following output on the command line:
    - i. 18:31:27: Running Optimization Problem for 2017-01-01  
00:00:00...
    - ii. C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:781: RuntimeWarning: overflow encountered in long\_scalars
    - iii. self.max\_big\_small\_squared < big\*small\*\*2:
    - iv. C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:782: RuntimeWarning: overflow encountered in long\_scalars
    - v. self.max\_big\_small\_squared = big\*small\*\*2
    - vi. Long-step dual simplex will be used

- b. This is an indication the optimization is running and computing a result.
- c. The following output indicate the optimization is complete:
  - i. Results have been saved to: `.\Results\ ...`
  - ii. Full runtime: `...`

```

Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

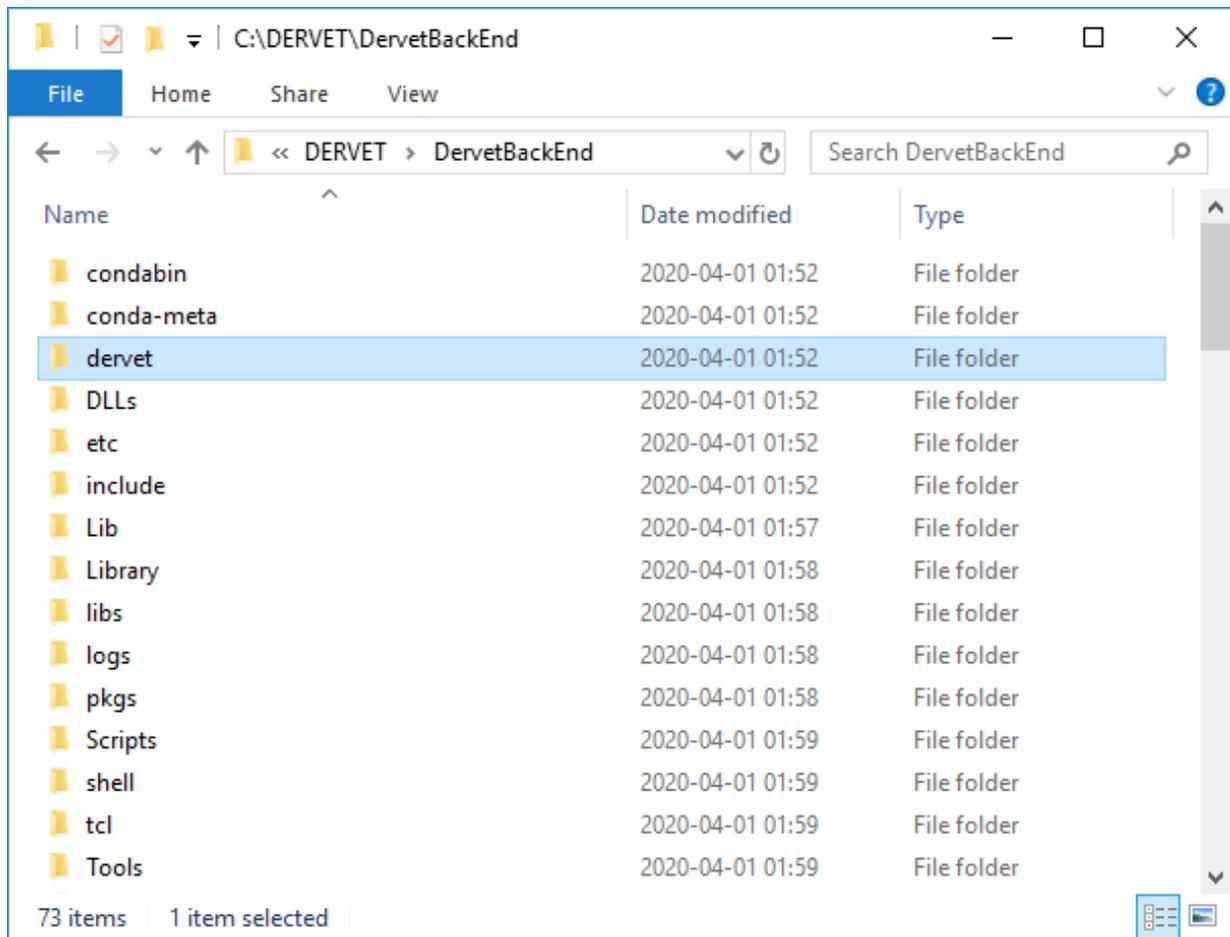
Loading personal and system profiles took 1366ms.
PS C:\DERVET\DerVetBackEnd> C:\DERVET\DerVetBackEnd\python.exe C:\DERVET\DerVetBackEnd\dervet\run_DERVET.py
C:\DERVET\DerVetBackEnd\dervet\Model_Parameters_Template_DER.csv
C:\DERVET\DerVetBackEnd\lib\site-packages\cvxpy\problems\problem.py:781: RuntimeWarning: overflow encountered
in long_scalars
    if self.max_big_small_squared < big*small**2:
Long-step dual simplex will be used
C:\DERVET\DerVetBackEnd\lib\site-packages\cvxpy\problems\problem.py:782: RuntimeWarning: overflow encountered
in long_scalars
    self.max_big_small_squared = big*small**2
Long-step dual simplex will be used
at hour 37
Results have been saved to: ./Results/_15_15_54_04_01_2020
DER results have been saved to: ./Results/_15_15_54_04_01_2020
PS C:\DERVET\DerVetBackEnd>

```

## Updating DER-VET

The DER-VET code is updated regularly. When new version of code is released, users can simply replace the previous version of the code with the newly released code **without needing to reinstall the environment** according the steps above.

1. Download the newly released and updated version of the DER-VET environment.
2. Unzip the standalone Python environment.
3. Locate the `dervet\` folder in the newly released environment.
4. Copy the updated code into the DER-VET environment and working directory.
  - a. Though previous DER-VET code does not need to be removed, its removal is recommended to ensure the latest, most updated code is being used.
5. Be sure to save and transfer any files from the previous `Data\` and `Results\` folders.



### Installing DER-VET GUI (Not required for command line users)

DER-VET GUI is an open-source user interface for EPRI's DER-VET software. This option enables users to run DER-VET from an interactive GUI in a self-hosted website. This section provides instructions on how to install, configure and use the DER-VET GUI.

#### ***Prerequisites for DER-VET GUI***

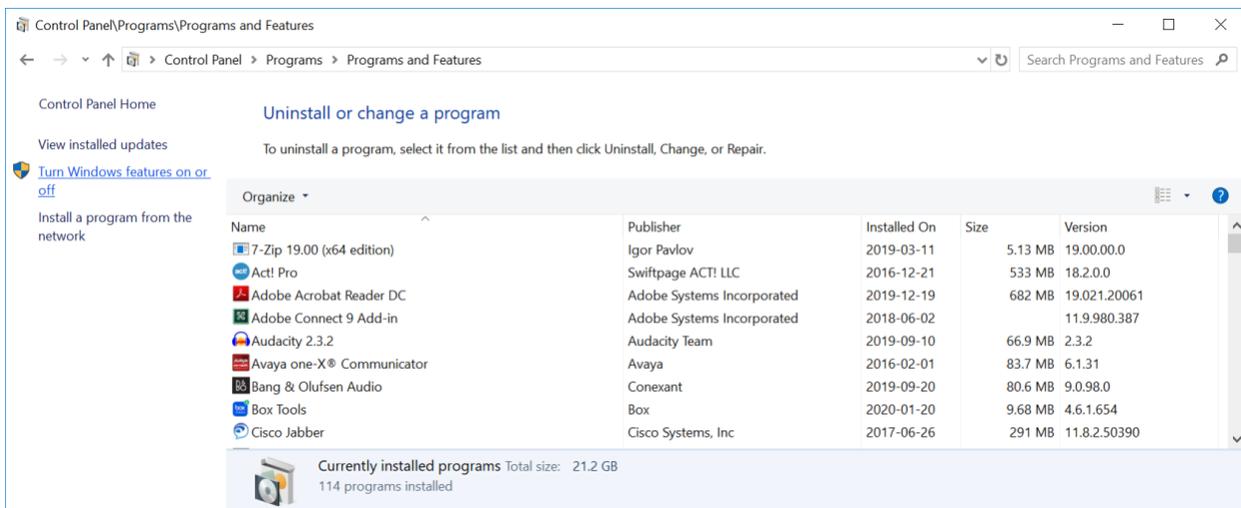
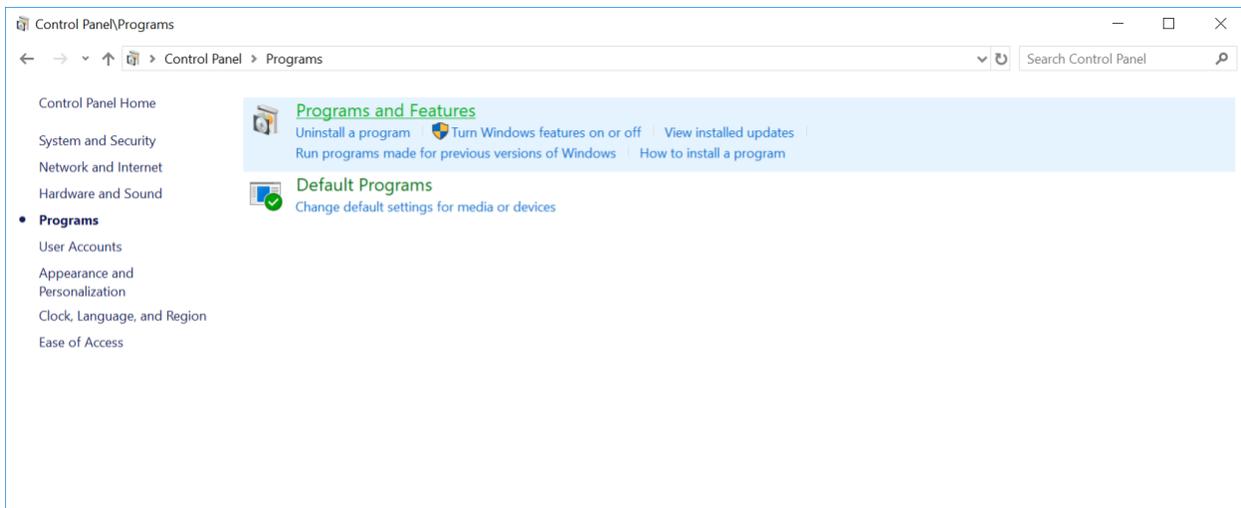
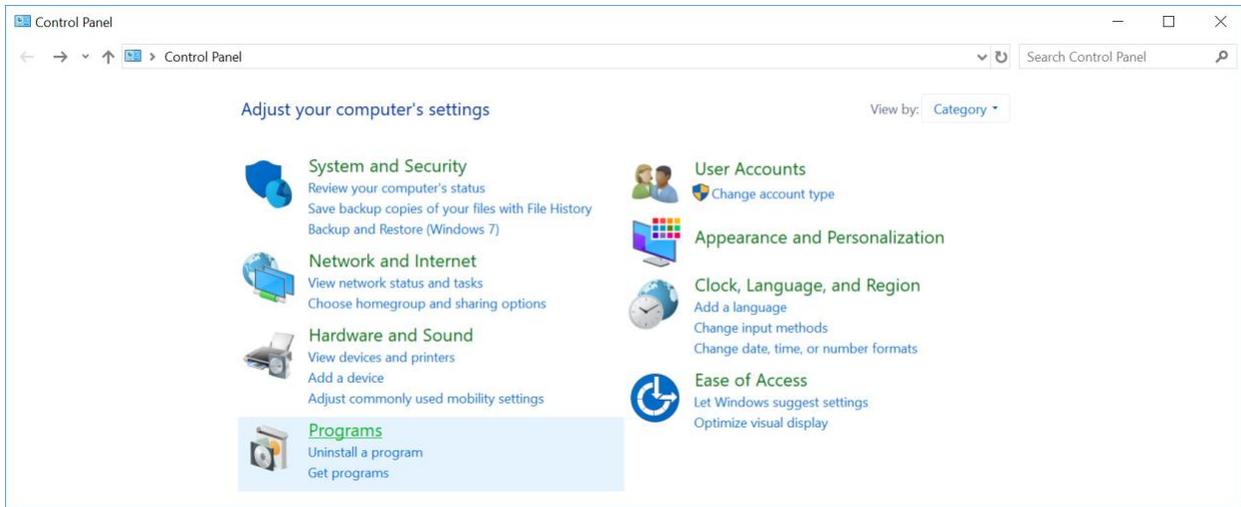
Your computer must use the Microsoft Windows operating system. DER-VET CE supports any personal version of Windows 7 or later and any server version of Windows Server 2012 or later.

Additionally, you must have the following software installed (detailed instructions below):

- Internet Information Services (IIS) 7 or later
- Microsoft SQL Server 2012 or later
- EPRI's DER-VET software

#### Installing Internet Information Services

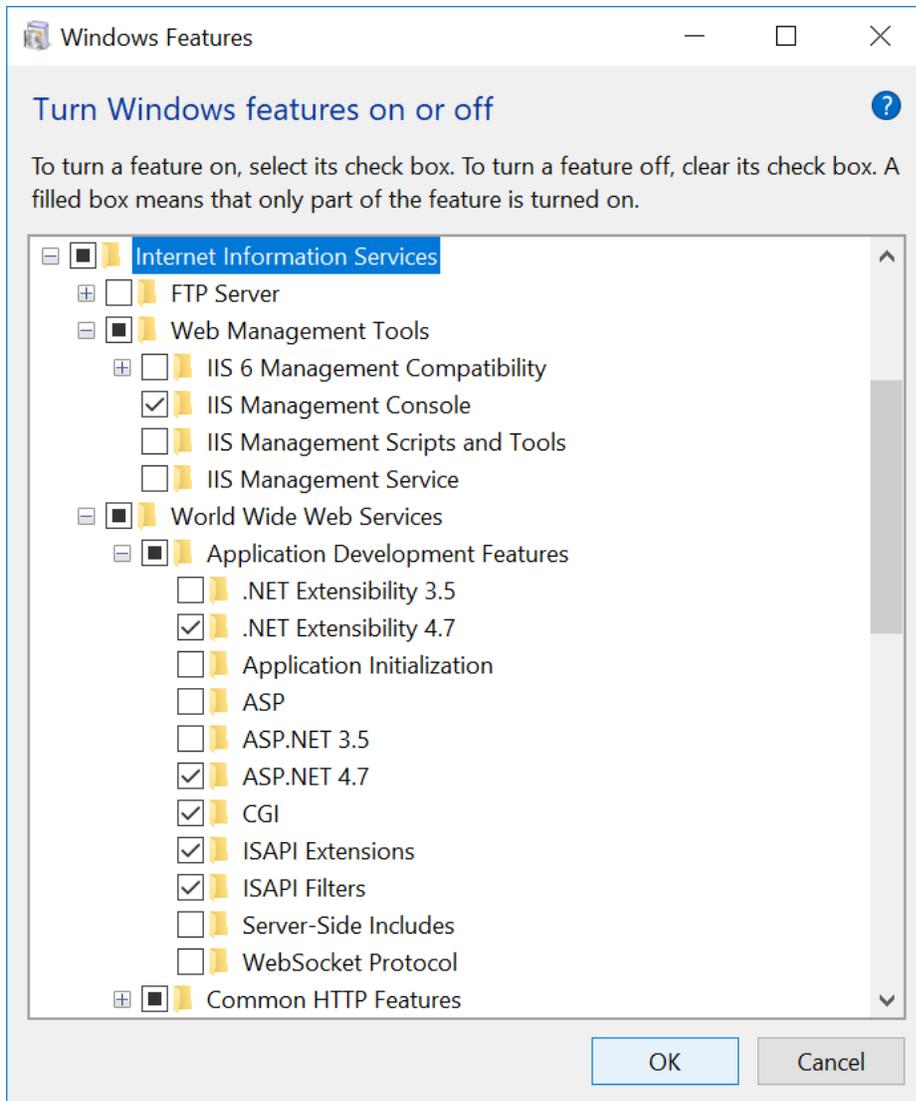
In Windows, open the **Control Panel**, go to **Programs and Features** and click **Turn Windows features on or off**. Depending on the version of Windows you are using, you should find an option titled **Internet Information Services** or **Web Server (IIS)**.



Expand this feature and make sure that the following options are enabled. The exact wording and location of these items will differ across different versions of Windows:

- **Internet Information Services or Web Server (IIS)**
  - Web Management Tools
    - IIS Management Console
  - World Wide Web Services
    - Application Development Features
      - .NET Extensibility 4.x
      - ASP.NET 4.x
      - ISAPI Extensions
      - ISAPI Filters

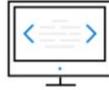
Seek to also check the Internet Information Systems >> World Wide Web Services >> Common HTTP Features >> **Static Content** checkbox to ensure web styles are served correctly to the web browser client.



## Installing Microsoft SQL Server

DER-VET CE requires **Microsoft SQL Server 2012** or later. If you do not already have Microsoft SQL Server installed, you can download and install [Microsoft SQL Server Express](#), which is a free edition of SQL Server.

## Or, download a free specialized edition



### Developer

SQL Server 2019 Developer is a full-featured free edition, licensed for use as a development and test database in a non-production environment.

[Download now](#) ↓



### Express

SQL Server 2019 Express is a free edition of SQL Server, ideal for development and production for desktop, web, and small server applications.

[Download now](#) ↓

# SQL Server 2019 Express Edition

Select an installation type:

## Basic

Select Basic installation type to install the SQL Server Database Engine feature with default configuration.

## Custom

Select Custom installation type to step through the SQL Server installation wizard and choose what you want to install. This installation type is detailed and takes longer than running the Basic install.

## Download Media

Download SQL Server setup files now and install them later on a machine of your choice.

SQL Server transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#)

15.1911.4567.1

SQL Server 2019



# Express Edition

Select an installation type:

## Basic

Select Basic installation type to install the SQL Server Database Engine feature with default configuration.

## Custom

Select Custom installation type to step through the SQL Server installation wizard and choose what you want to install. This installation type is detailed and takes longer than running the Basic install.

## Download Media

Download SQL Server setup files now and install them later on a machine of your choice.

SQL Server transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#)

15.1911.4567.1

SQL Server 2019



# Express Edition

Microsoft SQL Server License Terms

## MICROSOFT SOFTWARE LICENSE TERMS

### MICROSOFT SQL SERVER 2019 EXPRESS

These license terms are an agreement between you and Microsoft Corporation (or one of its affiliates). They apply to the software named above, which includes the media on which you received it, if any. The terms also apply to any Microsoft services or software updates (except to the extent such services or updates are accompanied by new or additional terms, in which case those different terms apply prospectively and do not alter your or Microsoft's rights relating to pre-updated software or services). **IF YOU COMPLY WITH THESE LICENSE TERMS, YOU HAVE THE RIGHTS BELOW FOR EACH SERVER YOU PROPERLY LICENSE. BY USING THE SOFTWARE, YOU ACCEPT THESE TERMS. IF YOU DO NOT ACCEPT THEM, DO NOT USE THE SOFTWARE. INSTEAD, RETURN IT TO THE RETAILER FOR A REFUND OR CREDIT. If you cannot obtain a refund there, contact Microsoft or the Microsoft affiliate serving your country for information about Microsoft's refund policies. See [www.microsoft.com/worldwide](http://www.microsoft.com/worldwide). In the United States and Canada, call (800) MICROSOFT or see [www.microsoft.com/info/nareturns.htm](http://www.microsoft.com/info/nareturns.htm) <<http://www.microsoft.com/info/nareturns.htm>>.**

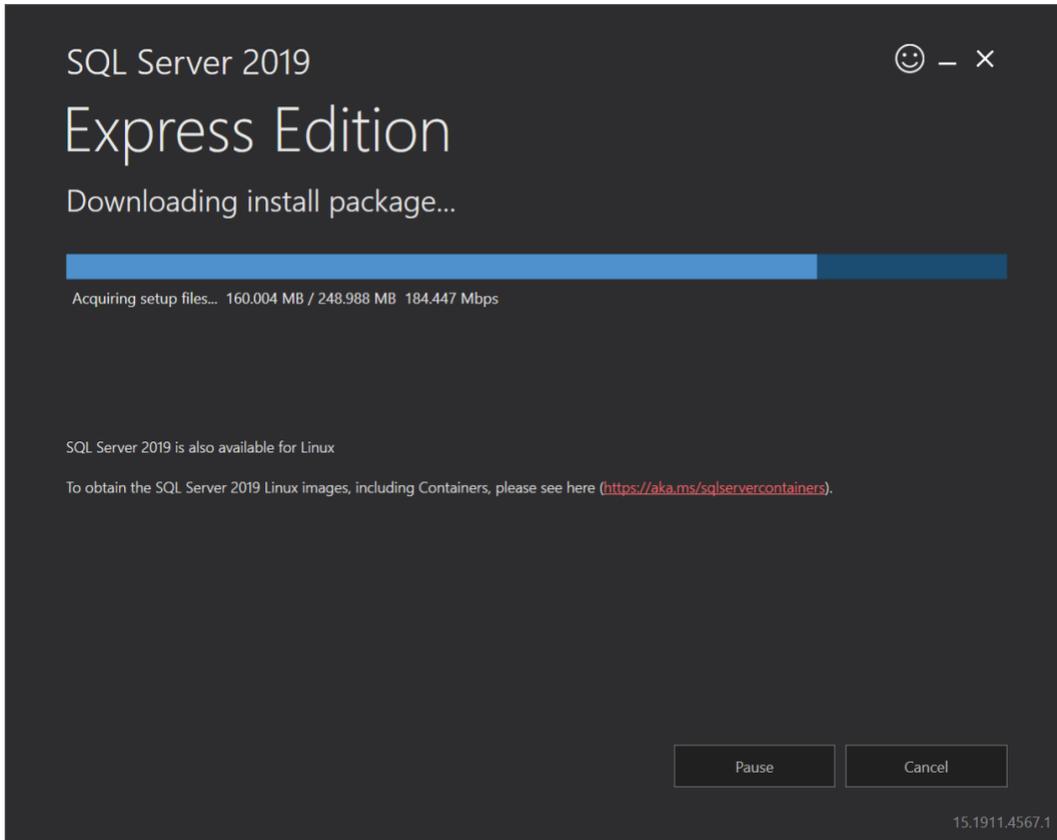
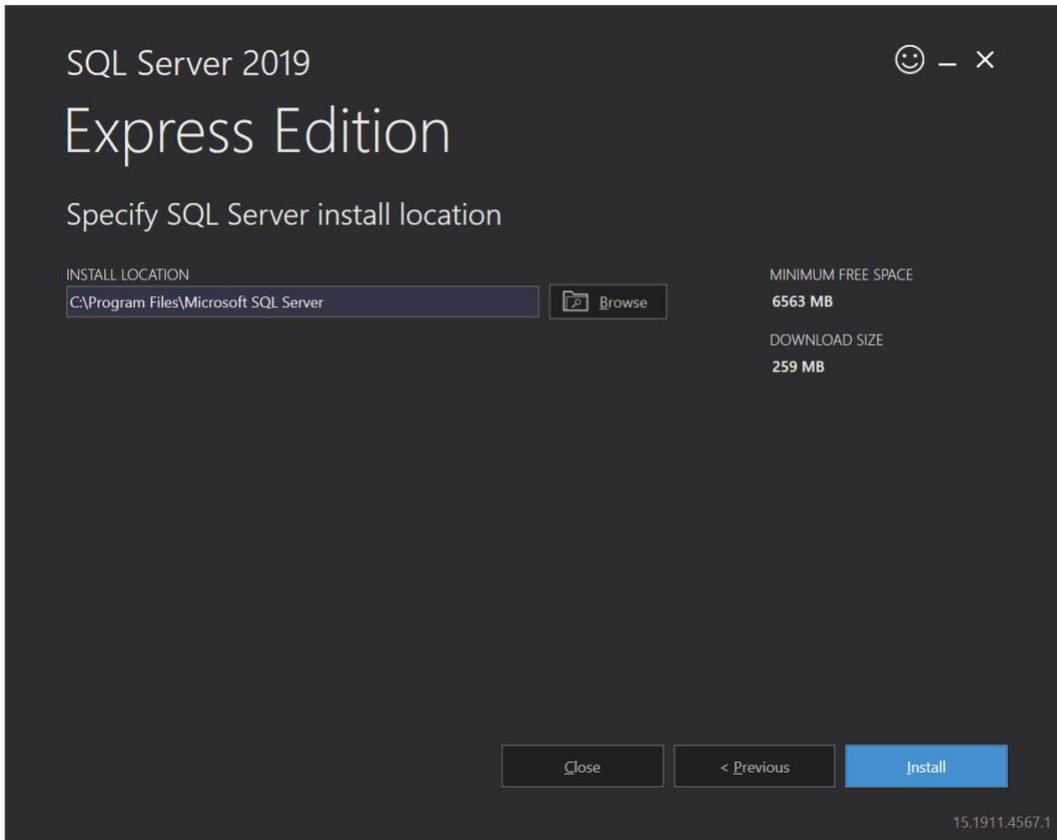
**IMPORTANT NOTICE: AUTOMATIC UPDATES TO PREVIOUS VERSIONS OF SQL SERVER.** If this software is installed on servers or devices running any supported editions of SQL Server prior to SQL Server 2019 (or components of any of them) this software will automatically update and replace certain files or features within those editions with files from this software. This feature cannot be switched off. Removal of these files may cause errors in

By clicking the "Accept" button, I acknowledge that I accept the License Terms and [Privacy Statement](#)

< Previous

Accept

15.1911.4567.1



SQL Server 2019 😊 — ✕

# Express Edition

Download successful!

---

Installing...

---

Installing SQL Server... Completed Action: InitializeMsiExtension, returned True

Samples

You use the Official Microsoft GitHub Repository containing code samples for SQL Server (<https://github.com/Microsoft/sql-server-samples/tree/master/samples>) for samples on connecting to a SQL Server database, development samples for using different features like In-Memory OLTP, R-Services and much more.

You could also use Azure SQL Database Samples and Reference Implementation Repository (<https://github.com/Azure/azure-sql-database-samples>) to get different reference implementation samples for C#, java, node.js, php, python, etc. You will need to change the server name appropriately in your connection string when using these samples.

Pause Cancel

15.1911.4567.1

SQL Server 2019 😊 — ✕

# Express Edition

Installation has completed successfully!

<p><b>INSTANCE NAME</b> SQLEXPRESS</p> <p><b>SQL ADMINISTRATORS</b> [REDACTED]</p> <p><b>FEATURES INSTALLED</b> SQLENGINE</p> <p><b>VERSION</b> 15.0.2000.5, RTM</p>	<p><b>CONNECTION STRING</b> Server=localhost\SQLEXPRESS;Database=master;Trusted_Connection=True</p> <p><b>SQL SERVER INSTALL LOG FOLDER</b> C:\Program Files\Microsoft SQL Server\150\Setup Bootstrap\Log\2020012</p> <p><b>INSTALLATION MEDIA FOLDER</b> C:\SQL2019\Express_ENU</p> <p><b>INSTALLATION RESOURCES FOLDER</b> C:\Program Files\Microsoft SQL Server\150\SSEI\Resources</p>
--	---

A computer restart is required to complete your installation.

⌂ Connect Now Customize Install SSMS Close

15.1911.4567.1

## Installing SQL Server Management Studio

Also install [SQL Server Management Studio](#). **SQL Server Management Studio (SSMS)** is a tool for managing SQL Server databases.



Download SQL Server Management Studio (SSMS)

11/03/2019 • 4 minutes to read • +26

**APPLIES TO:** SQL Server, Azure SQL Database, Azure Synapse Analytics (SQL DW), Parallel Data Warehouse

SQL Server Management Studio (SSMS) is an integrated environment for managing any SQL infrastructure, from SQL Server to Azure SQL Database. SSMS provides tools to configure, monitor, and administer instances of SQL Server and databases. Use SSMS to deploy, monitor, and upgrade the data-tier components used by your applications, and build queries and scripts.

Use SSMS to query, design, and manage your databases and data warehouses, wherever they are - on your local computer, or in the cloud.

SSMS is free!

**Download SSMS**

[Download SQL Server Management Studio \(SSMS\)](#)

SSMS 18.4 is the latest general availability (GA) version of SSMS. If you have a previous GA version of SSMS 18 installed, installing SSMS 18.4 upgrades it to 18.4.

SSMS-Setup-ENU.exe

Show all



RELEASE 18.4

# Microsoft SQL Server Management Studio

Welcome. Click "Install" to begin.

Location:

C:\Program Files (x86)\Microsoft SQL Server Management Studio 18

Change

By clicking the "Install" button, I acknowledge that I accept the [License Terms](#) and [Privacy Statement](#).

SQL Server Management Studio transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#).

Install

Close



RELEASE 18.4

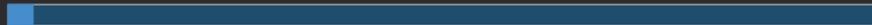
# Microsoft SQL Server Management Studio

Package Progress



Microsoft Visual C++ 2017 Redistributable (x64) - 14.16.27029

Overall Progress



Cancel



RELEASE 18.4

## Microsoft SQL Server Management Studio

Restart required in order to complete setup.

All specified components have been installed successfully.

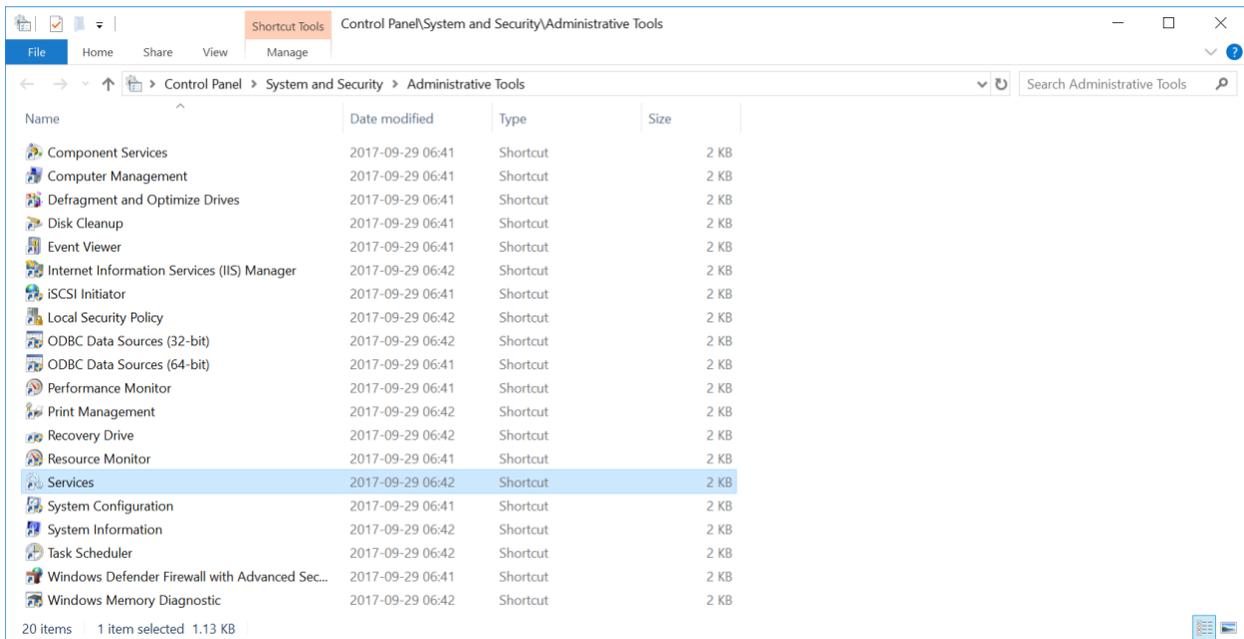
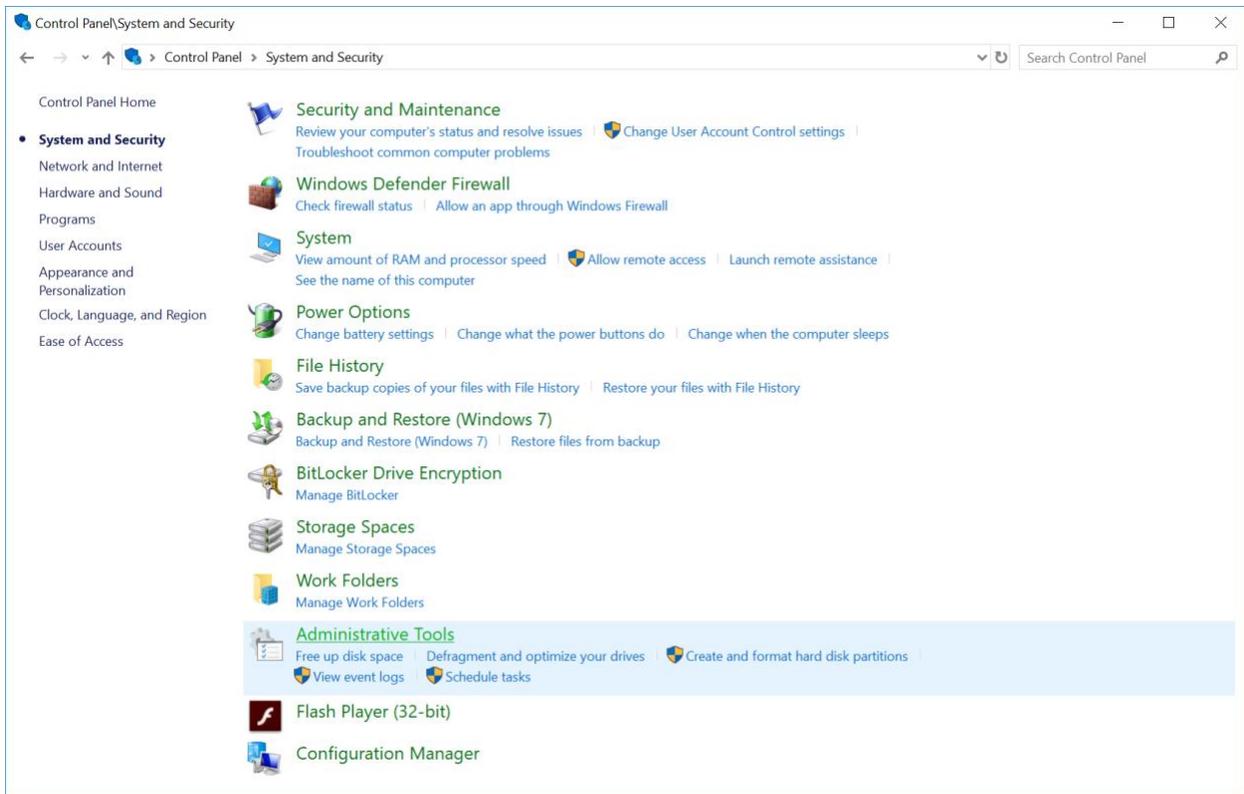
The computer needs to be restarted before setup can continue.

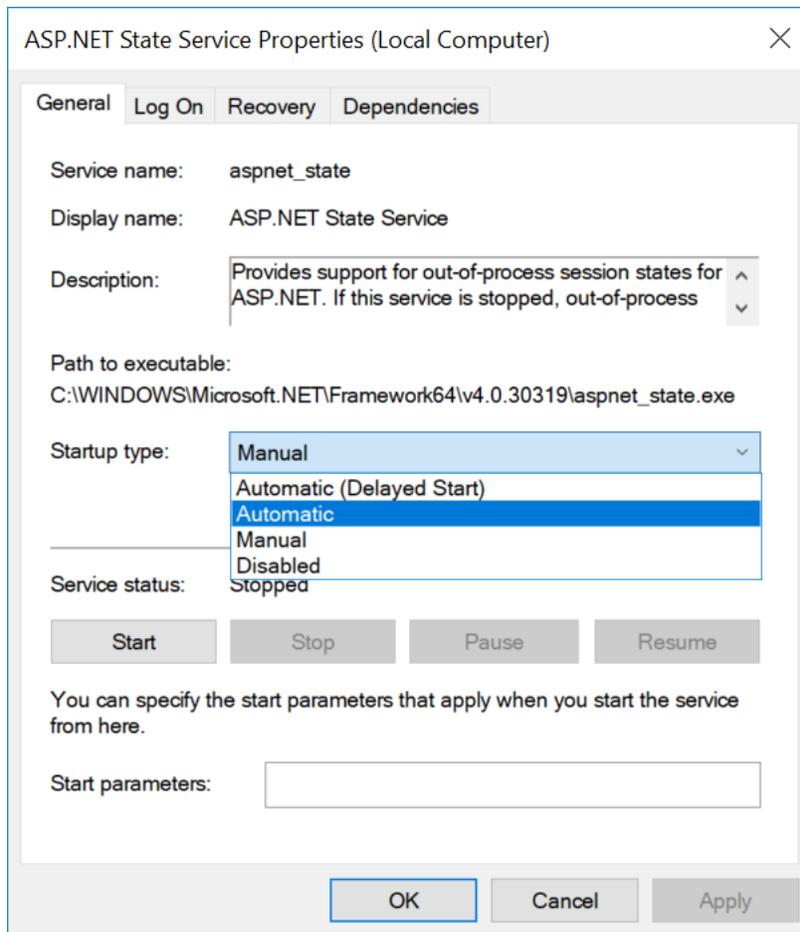
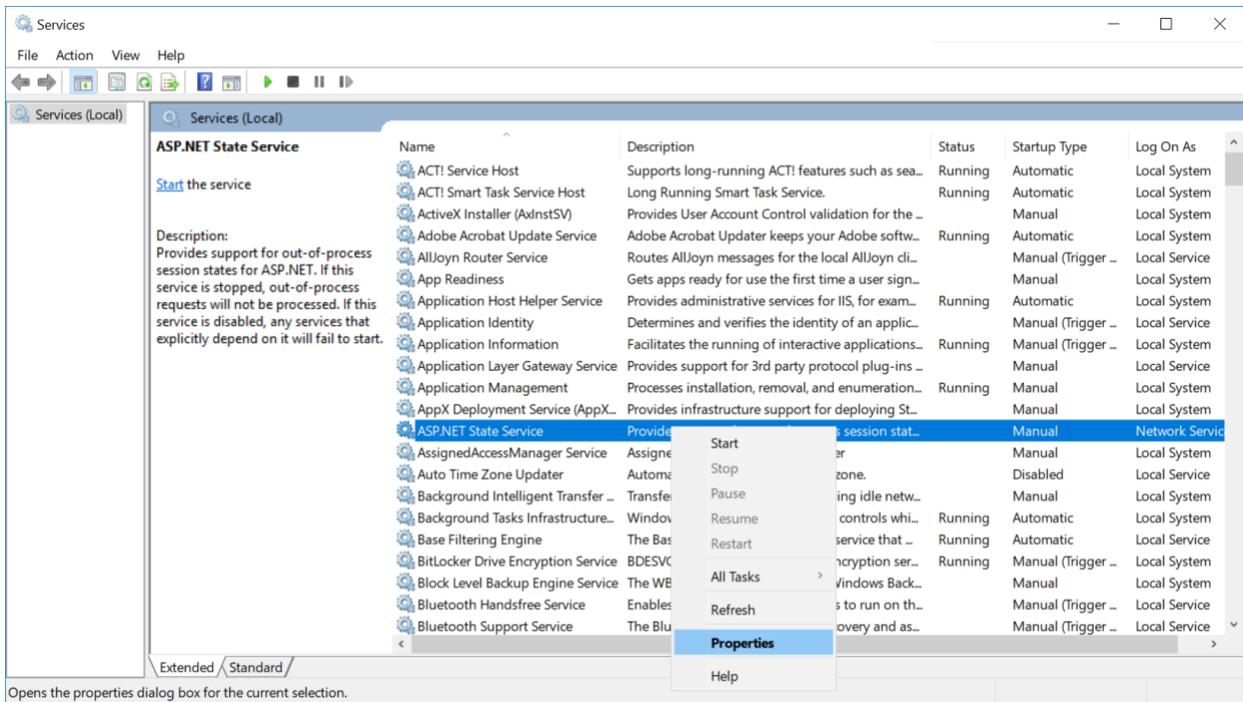
Restart

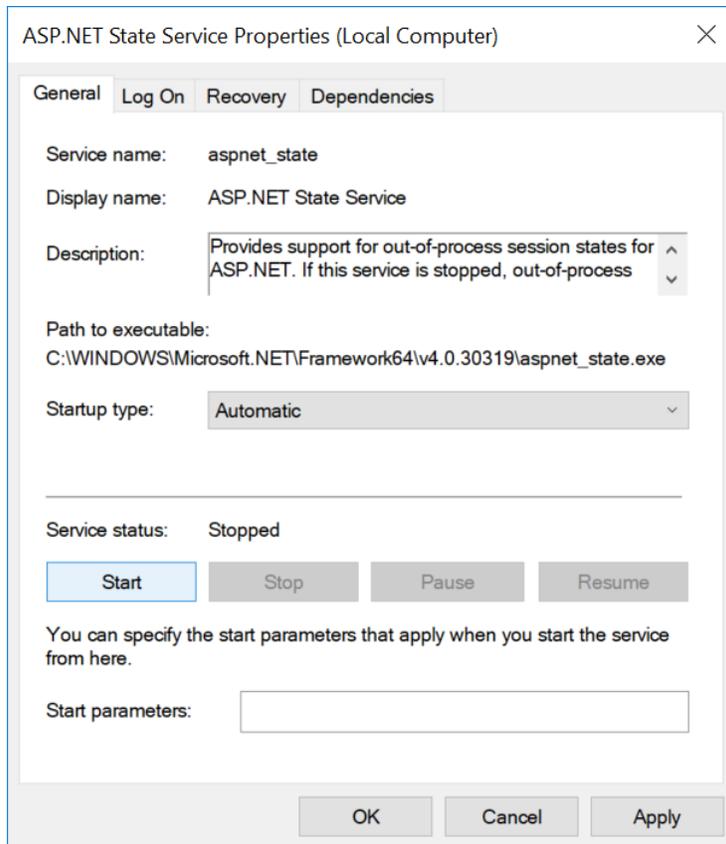
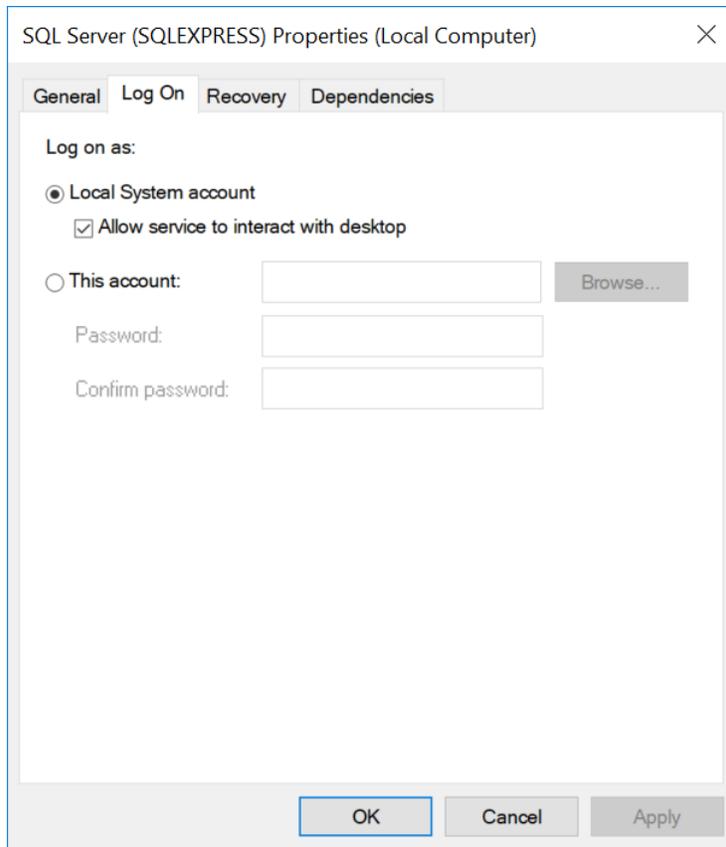
Close

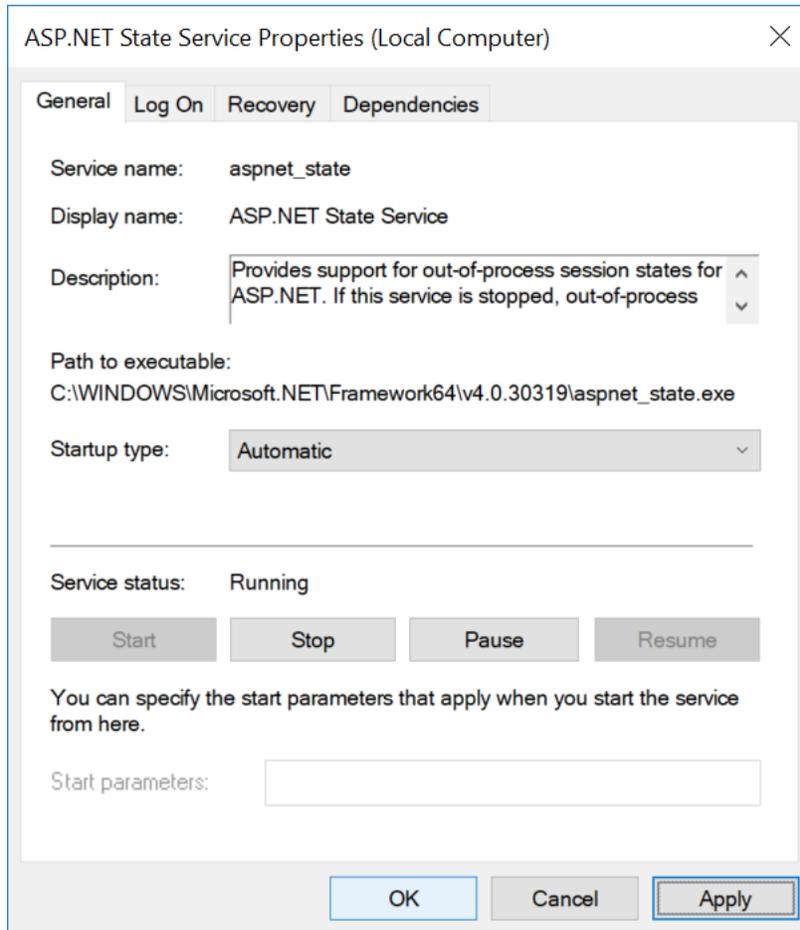
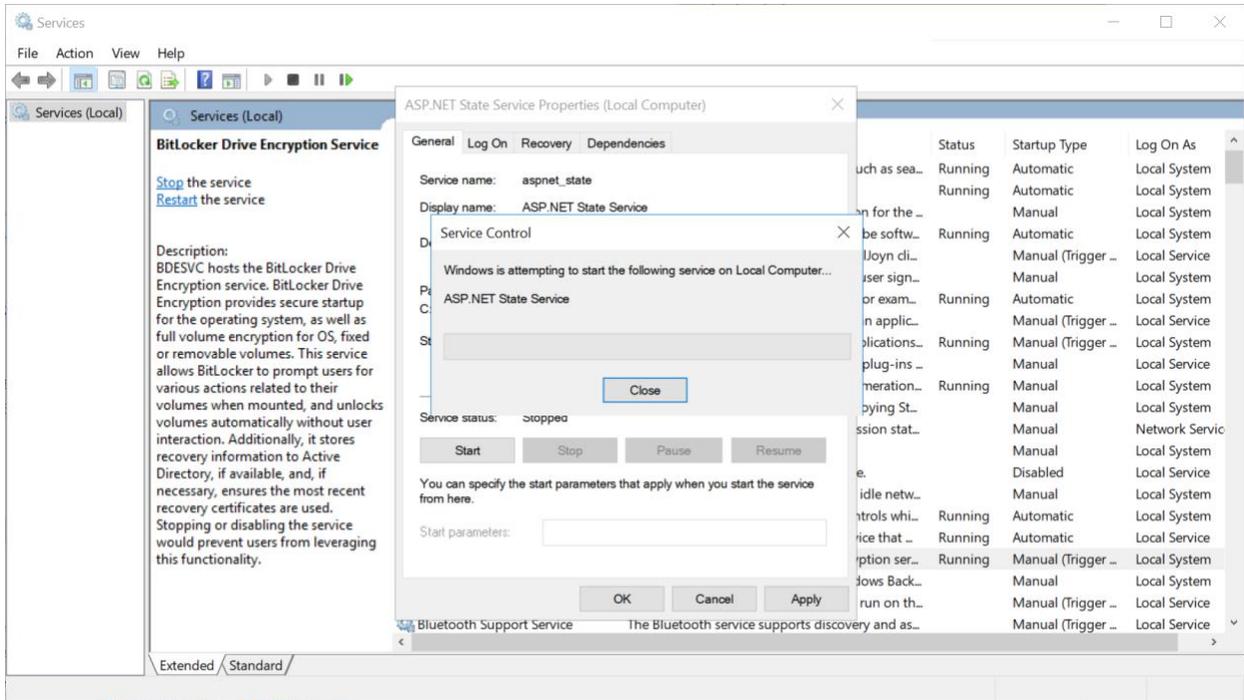
### Configuring the ASP.NET State Server Service

After installing Internet Information Services, you need to ensure that the ASP.NET State Server service is running and is configured to automatically run on system startup. Go to **Control Panel** and drill into the **Administrative Tools** section. Next, open the **Services** tool.









In the list of services, you should see one named **ASP.NET State Server**. Right-click this service and select **Properties**. Make sure the **Startup** type is set to **Automatic** and that the service is currently running. If its status is Stopped, click the **Start** button to start the service.

It is also recommended to click on **Logon** tab and select **Log on as: Local System account** and **Allow service to interact with desktop**. These options will simplify and stabilize the startup of the SQL Server (SQLEXPRESS) as well as allow for login via SQL Server Management Studio (SSMS).

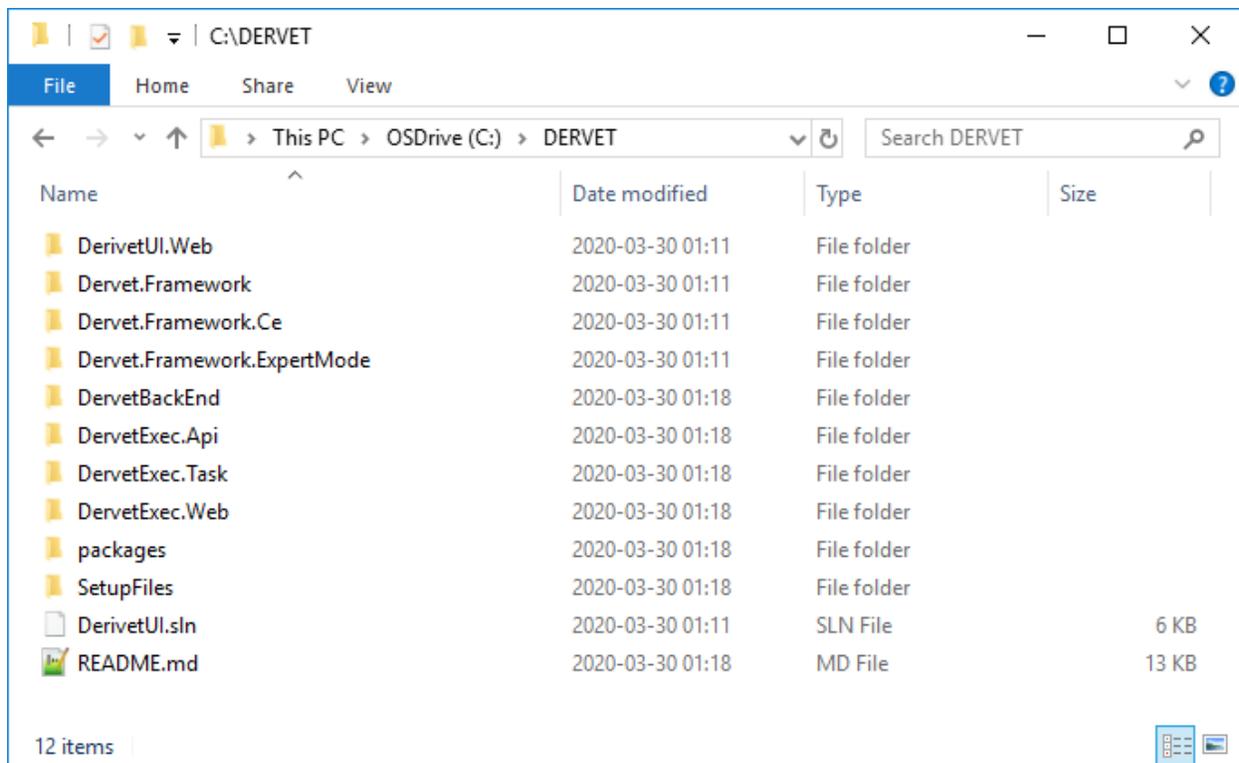
### ***Installing DER-VET GUI***

The DER-VET download contains three folders:

- **SetupFiles** – contains database scripts for creating the necessary database objects in Microsoft SQL Server.
- **DerivetUI.Web** – a website that serves as the user interface. This is the website that you will use to specify the inputs that get passed to EPRI's DER-VET software, and will graph the results that get generated.
- **DervetExec.Web** – a website that takes the inputs entered through the user interface website (**DerivetUI.Web**), executes EPRI's DER-VET software, and then returns the results to the user interface for reporting.

Create a folder on your hard drive and copy these three folders there. In order to provide example configuration syntax, this documentation will proceed as if the contents of the download were placed in a folder named C:\DERVET, meaning that there would be the following directory structure:

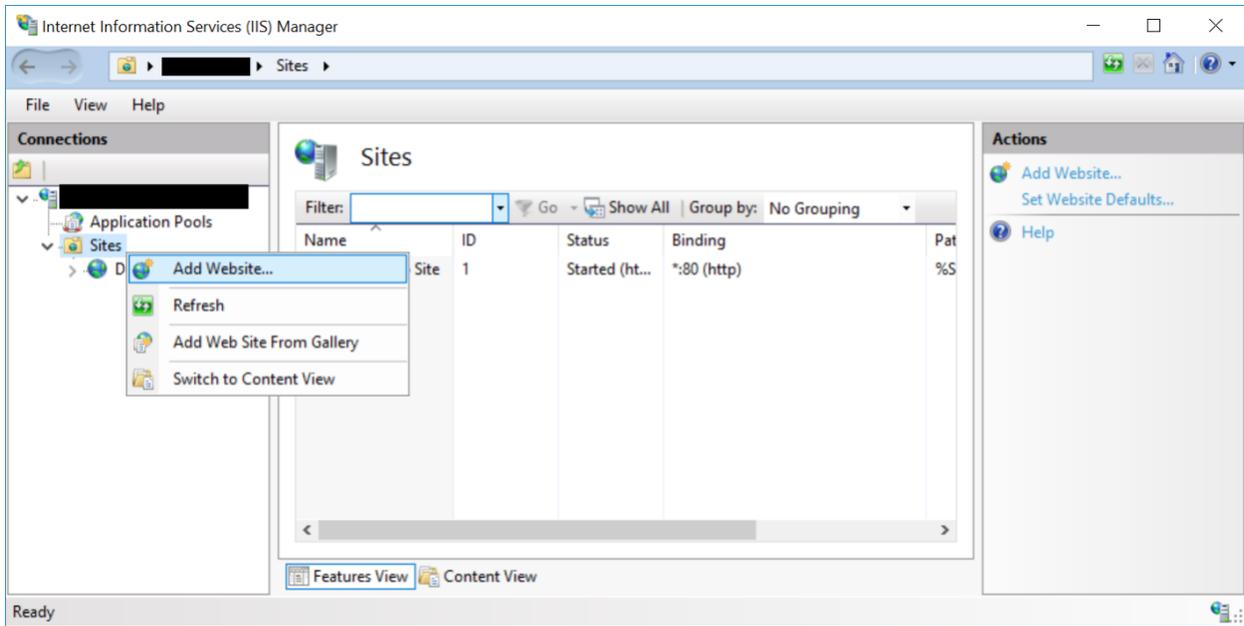
- C:\DERVET
  - C:\DERVET\DerivetUI.Web
  - C:\DERVET\Dervet.Framework
  - C:\DERVET\Dervet.Framework.Ce
  - C:\DERVET\Dervet.Framework.ExpertMode
  - C:\DERVET\DervetBackEnd
  - C:\DERVET\DervetExec.Api
  - C:\DERVET\DervetExec.Task
  - C:\DERVET\DervetExec.Web
  - C:\DERVET\packages
  - C:\DERVET\SetupFiles
  - C:\DERVET\DerivetUI.sln



## Creating the Websites in IIS

The first step is to create websites in Internet Information Services (IIS) for both **DerivetUI.Web** and **DervetExec.Web**. Launch Internet Information Services and perform the following steps:

1. Click on the server name to reveal the Sites folder.
2. Right-click on the Sites folder and choose Add Website
3. Enter **DervetExec.Web** as the Site name and set the Physical path to the folder where the **DervetExec.Web** site resides (e.g., **C:\DERVET\DervetExec.Web**). Update the port number, if needed (e.g., **8088**).
4. Click the OK button



**Add Website**

Site name:  Application pool:

Content Directory

Physical path:

Pass-through authentication

Binding

Type:  IP address:  Port:

Host name:

Example: www.contoso.com or marketing.contoso.com

Start Website immediately

Repeat these steps to create a website for **DerivetUI.Web**:

1. Click on the server name to reveal the Sites folder.
2. Right-click on the Sites folder and choose Add Website
3. Enter **DerivetUI.Web** as the Site name and set the Physical path to the folder where the **DerivetUI.Web** site resides (e.g., C:\DERVET\DerivetUI.Web). Update the port number, if needed (e.g., 8089).
4. Click the OK button

Add Website

Site name: DerivetUI.Web Application pool: DerivetUI.Web Select...

Content Directory

Physical path: C:\DERVET\DerivetUI.Web ...

Pass-through authentication

Connect as... Test Settings...

Binding

Type: http IP address: All Unassigned Port: 8089

Host name:

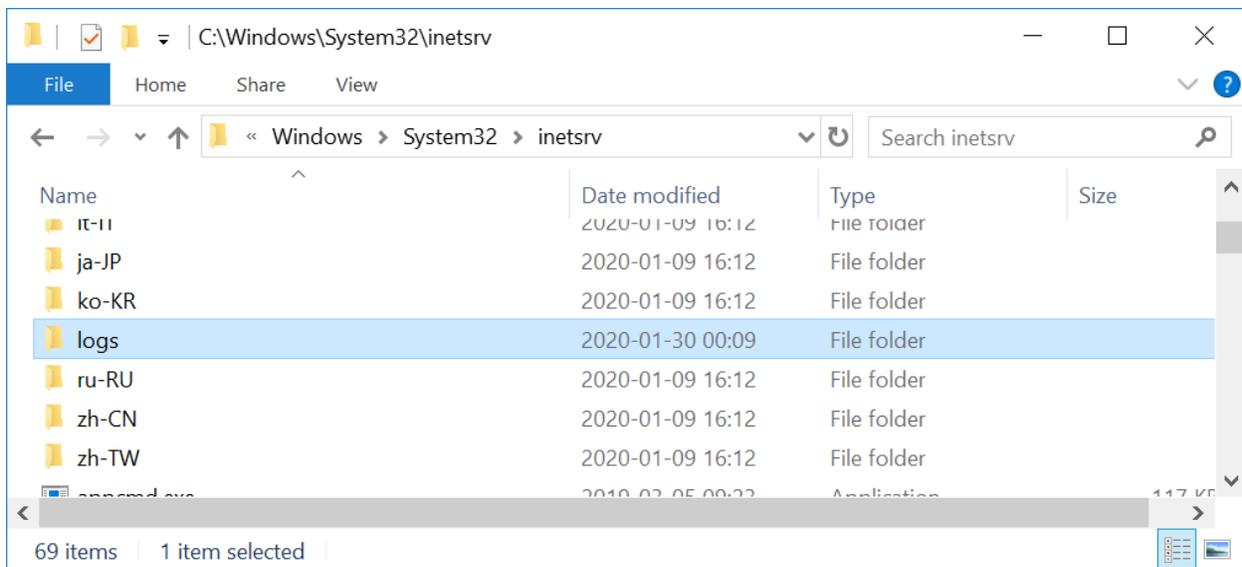
Example: www.contoso.com or marketing.contoso.com

Start Website immediately

OK Cancel

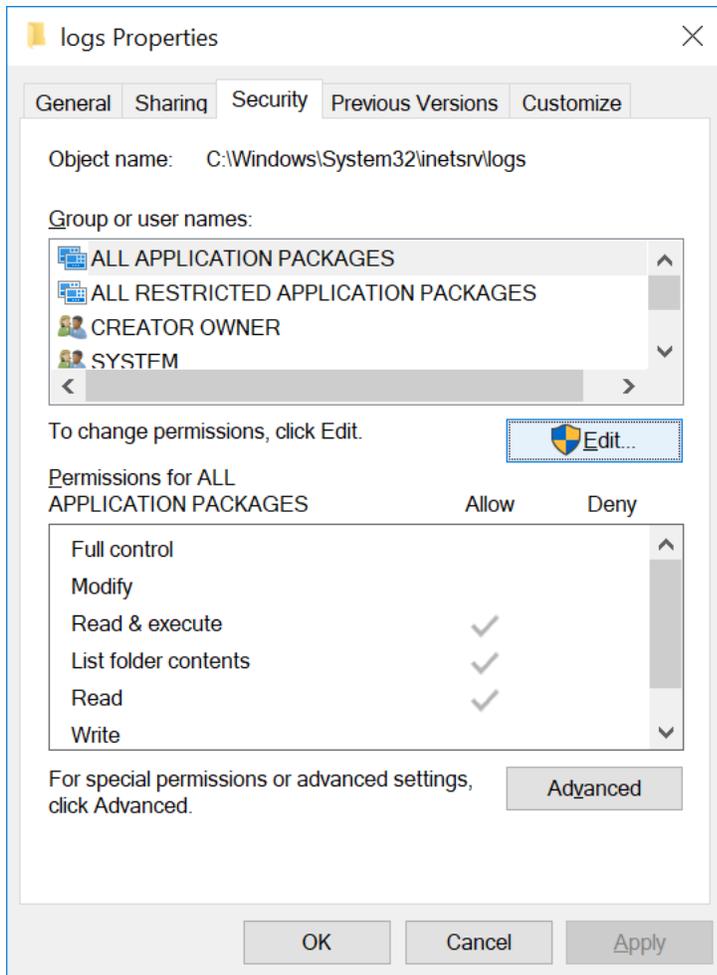
## Create Log Folder

Next, create a folder named logs in the Windows folder `Windows\System32\inetsrv` (e.g., `C:\Windows\System32\inetsrv\logs`). This is the folder where EPRI's DER-VET software will place log files intended for experienced developers to troubleshoot any issues with the software.

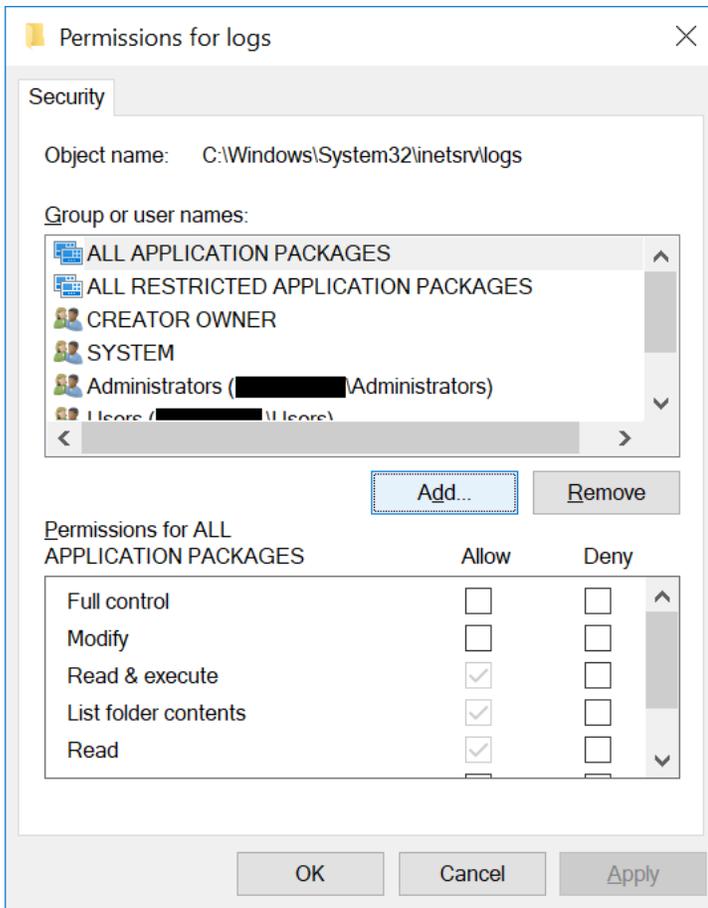


Configure the permissions to allow anyone full control to this folder. To do so, follow these steps:

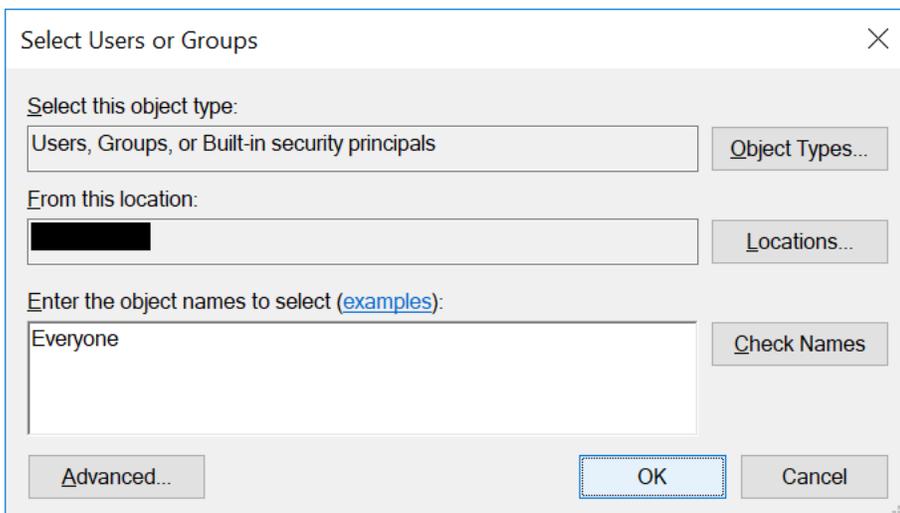
1. Right-click on the **logs** folder and choose **Properties**.
2. Go to the **Security** tab and click **Edit**.



3. Click Add and then type in Everyone and click OK.

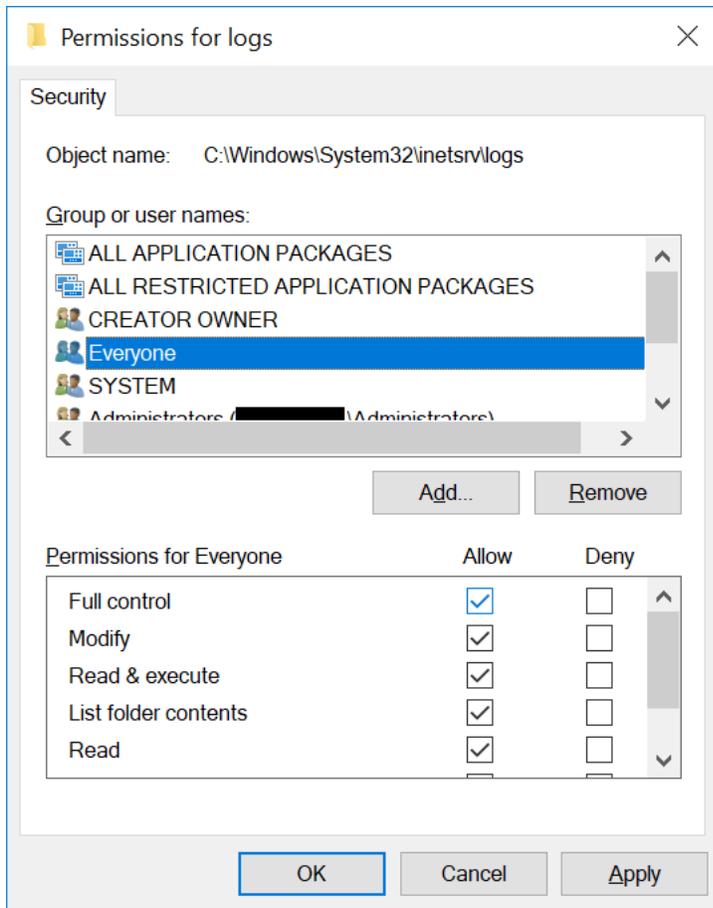


4.



5.

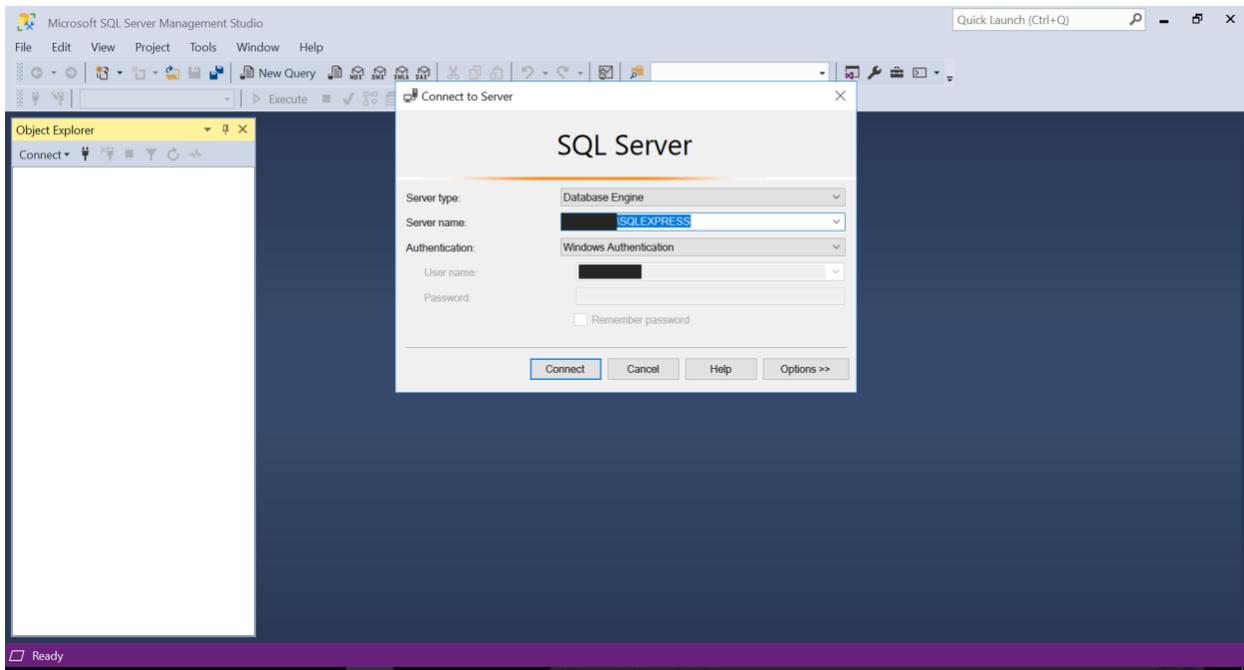
6. Check the Full control checkbox and click OK.



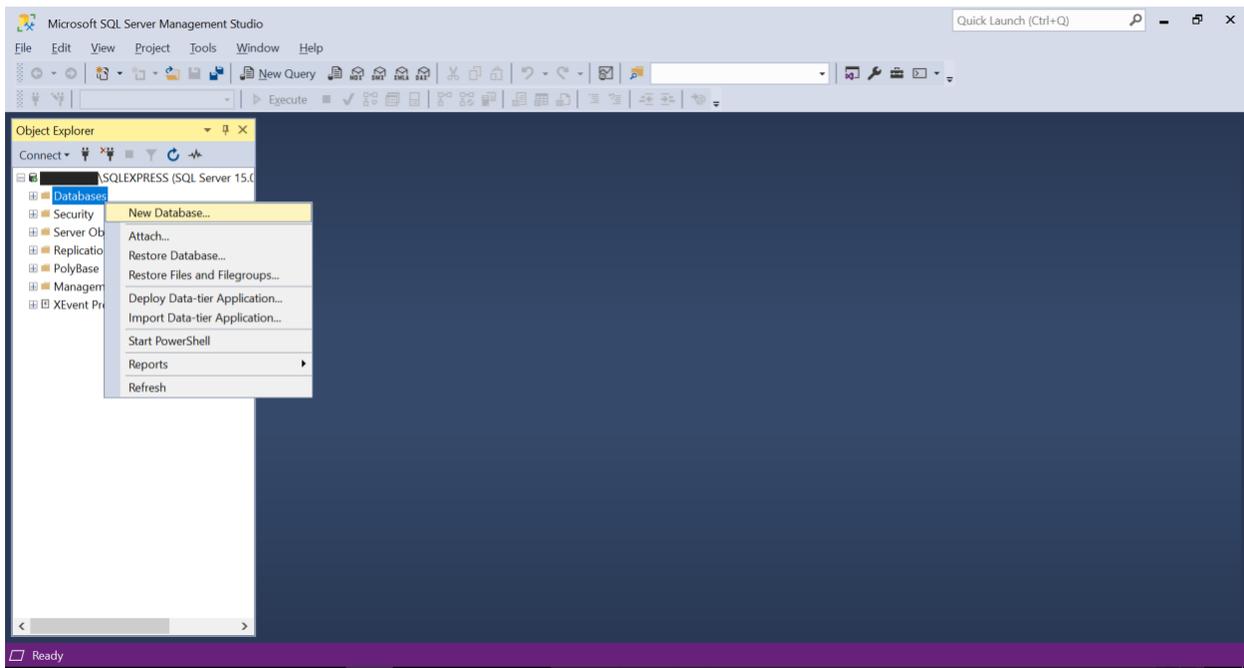
Note: If you do not create the logs folder or if you do not grant the appropriate permissions then DER-VET GUI will fail whenever it attempts to run EPRI's DER-VET software and you will not be able to perform any analyses from DER-VET GUI.

### Configuring Database for DER-VET GUI

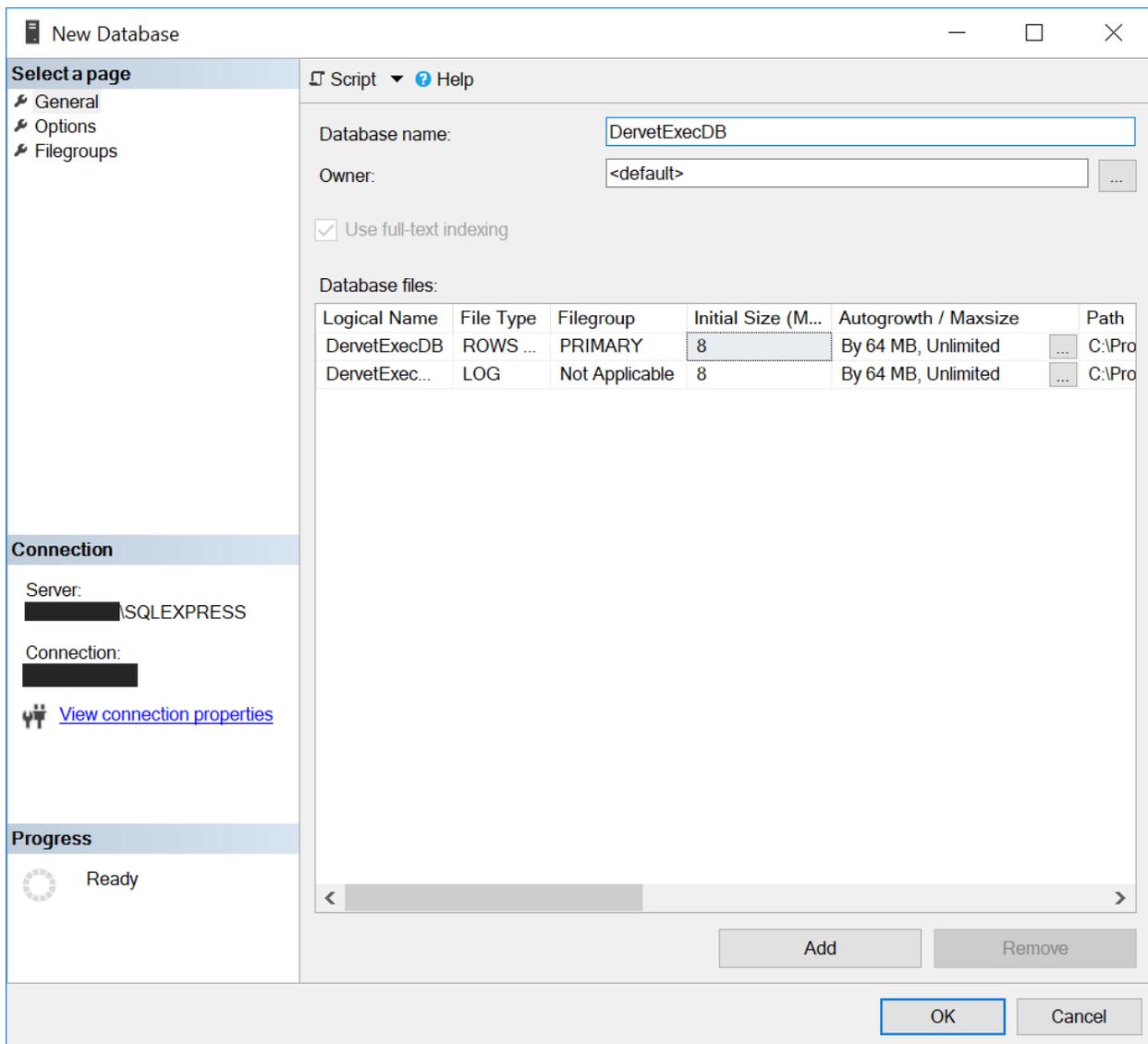
Launch **SQL Server Management Studio (SSMS)** and **Connect** to the local server designated as **SQLEXPRESS**.



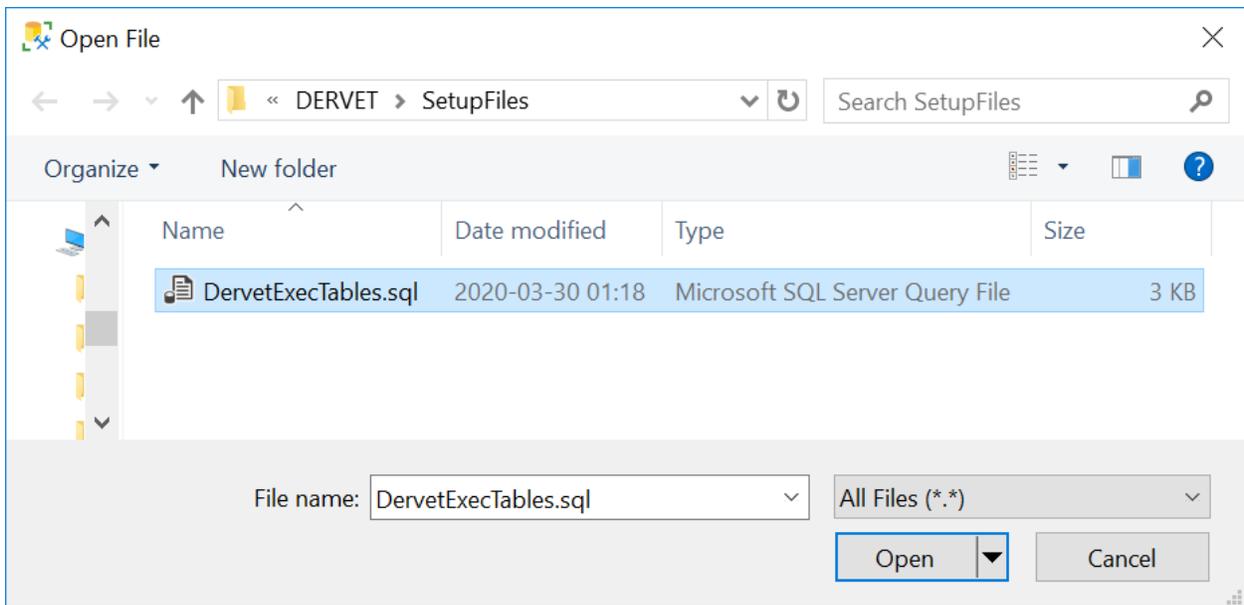
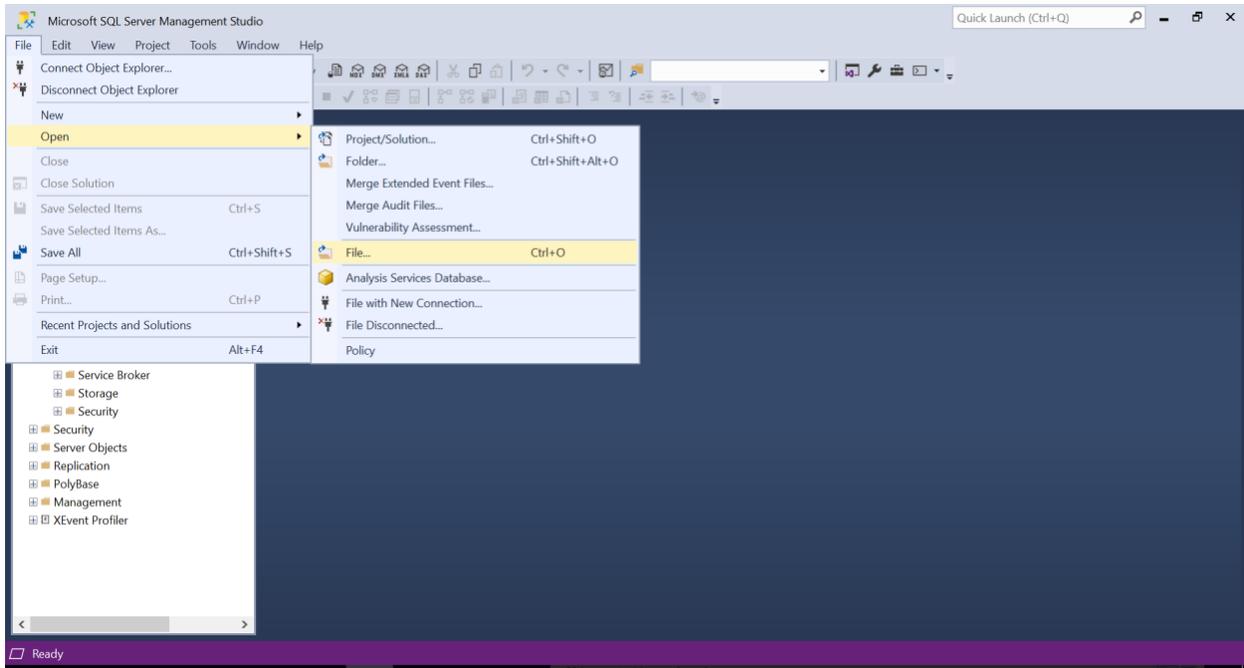
Right-click on the Databases tab and choose New Database.



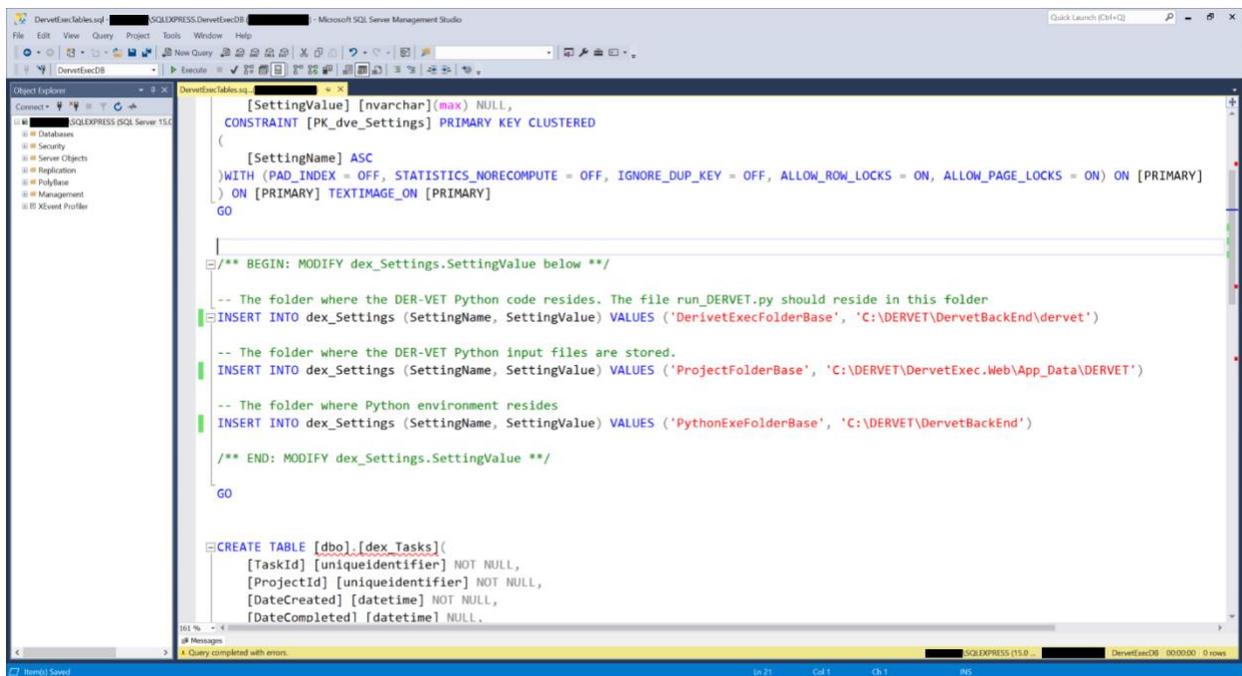
Enter the Database name DervetExecDB.



Next, open the SetupFiles\DervetExecTables.sql file in SSMS.



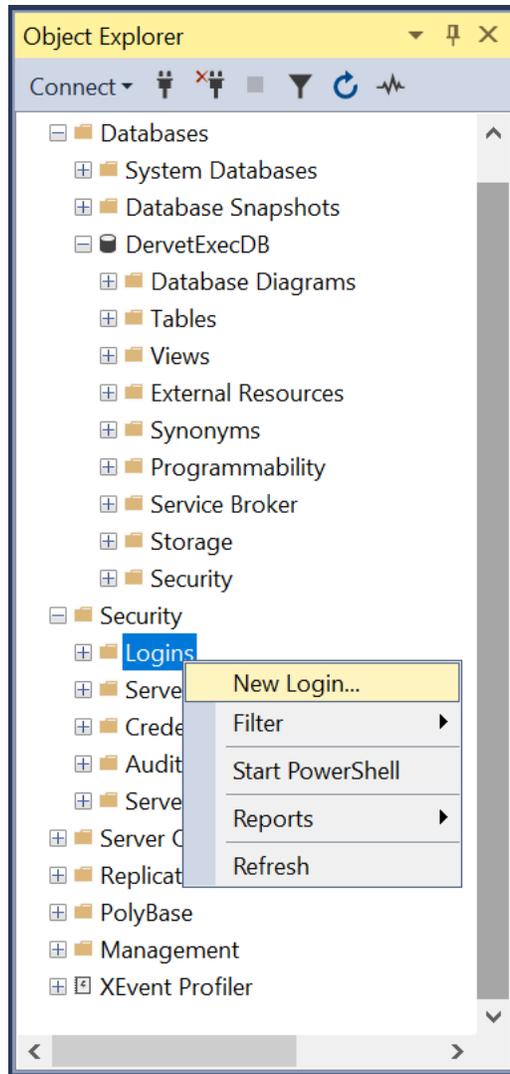
Click the Execute button to execute the SQL script.



The `DerivetExec.Web` website needs to be able to access the `DerivetExecDB` database. To accomplish this, you must create an account in SQL Server for the security context under which the `DerivetExec.Web` website runs. When you created the `DerivetExec.Web` website you specified the Application Pool the website would run under. Unless you explicitly changed this, the Application Pool is named `DerivetExec.Web`.

To grant the Application Pool `DerivetExec.Web` access to the `DerivetExecDB` database, perform the following steps:

1. From SQL Server Management Studio, expand the top-level Security folder. (Note that there is also a Security folder under each Database - it is imperative that you expand the top-level Security folder.)
2. Right-click on the Logins folder and choose `New Login`.



3. In Login name enter IIS APPPOOL\DervetExec.Web.

Login - New

Select a page

- General
- Server Roles
- User Mapping
- Securables
- Status

Script Help

Login name: IIS APPPOOL\DervetExec.Web Search...

Windows authentication  
 SQL Server authentication

Password:   
 Confirm password:   
 Specify old password  
 Old password:   
 Enforce password policy  
 Enforce password expiration  
 User must change password at next login

Mapped to certificate   
 Mapped to asymmetric key   
 Map to Credential  Add

Credential	Provider

Remove

Default database: master

Default language: <default>

OK Cancel

Connection

Server: [REDACTED] SQLEXPRESS

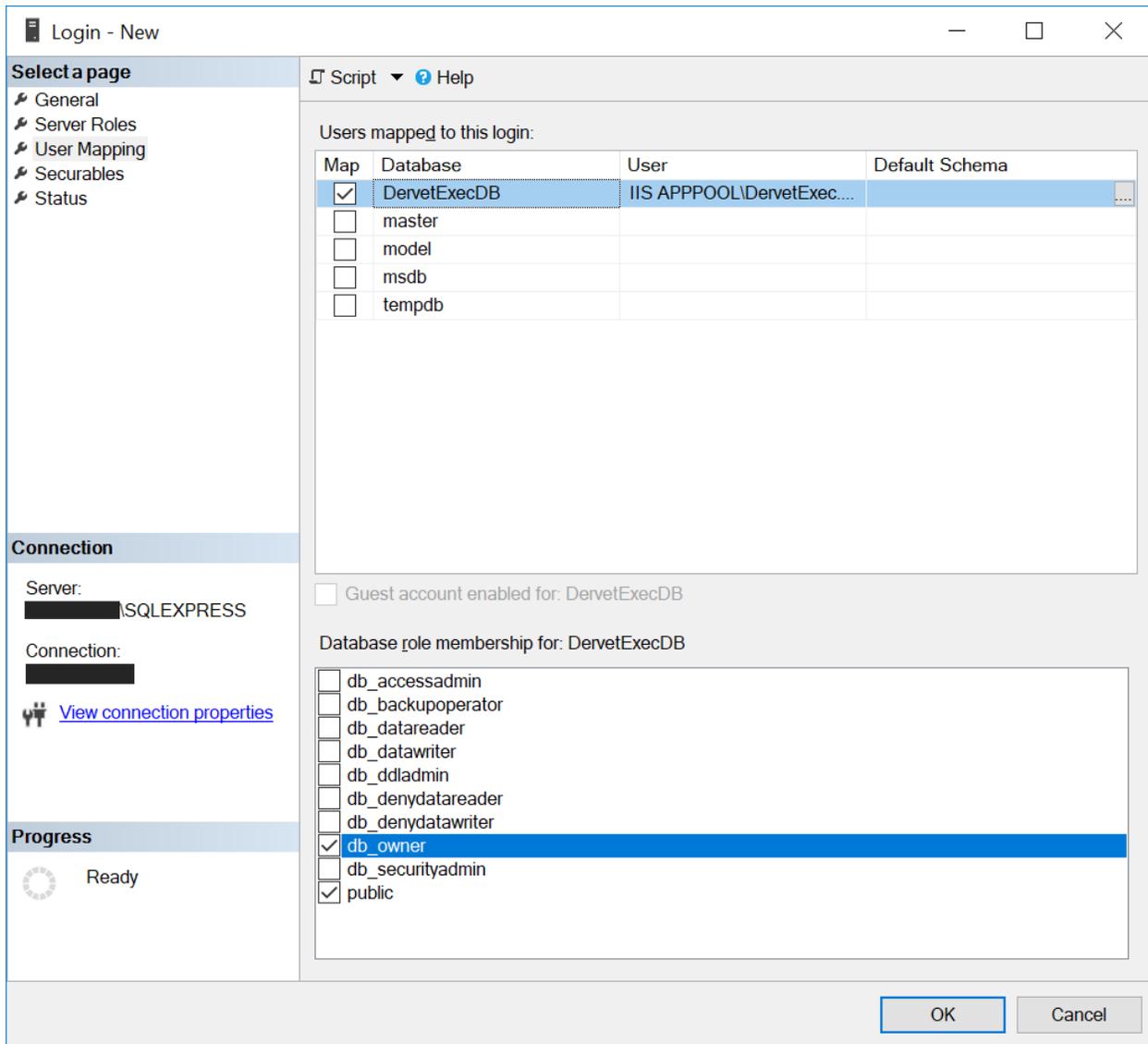
Connection: [REDACTED]

[View connection properties](#)

Progress

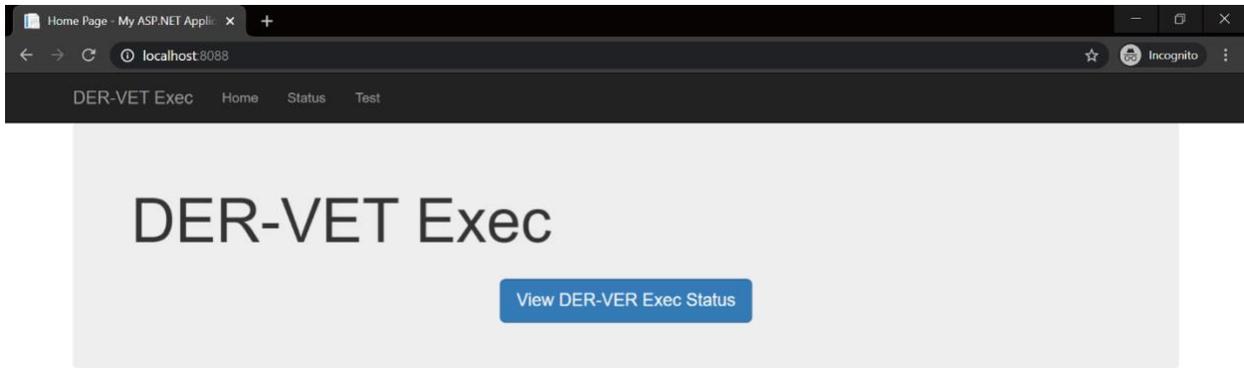
Ready

- Click on the User Mapping page on the left.
- Check the DervetExecDB database in the top section. Once checked, review the Database role membership options in the bottom. Ensure that the db\_owner checkbox is checked.
- Click OK.



## Running DER-VET GUI

To test the installation and configuration, start by launching a web browser and visit the DervetExec.Web website. The URL for this website will depend on the port number you entered when creating the website in IIS. Say you used **8088** - in this case you would visit <http://localhost:8088>. You should see a message titled DER-VET Exec with a button labeled View DER-VET Exec Status. If you don't see this message or get some sort of error, that indicates that the DervetExec.Web website was not setup or configured properly.



Click the View DER-VET Exec Status button. You should be taken to a login page. Here, enter the login credentials:

- Username: admin
- Password: energy

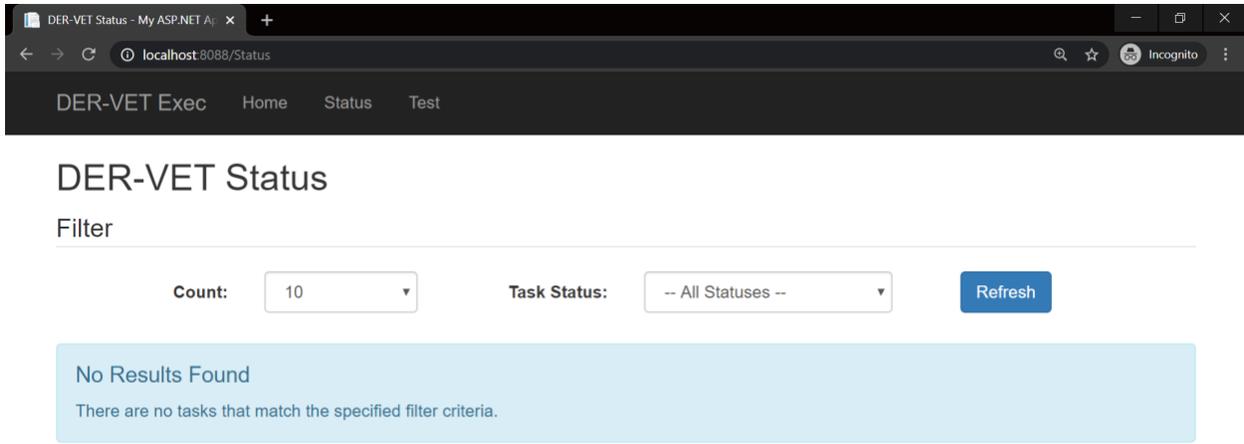
These are specified in the `DervetExec.Web` website's configuration file. Once you've authenticated, you should see a screen that lists the DER-VET optimizations that have been run to date (which, at this point, will be none). If you get an error when viewing this page in particular, it likely indicates an issue with the database. Either the database was not installed or the security is not appropriately configured.



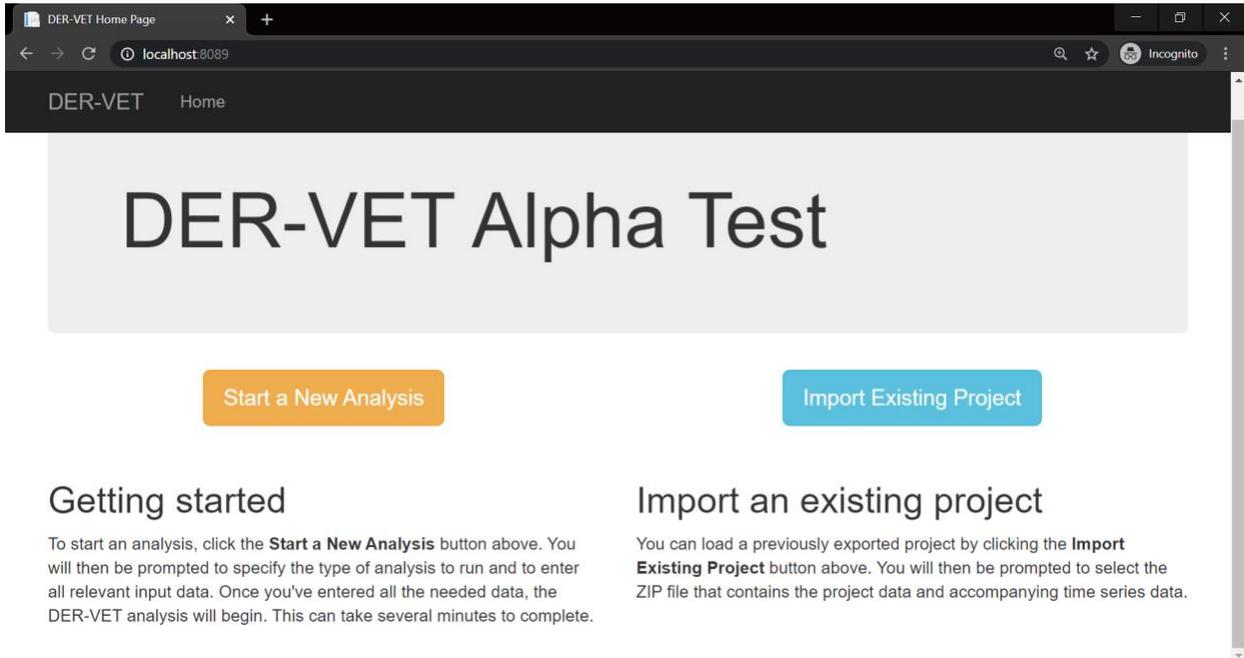
## Login

Username

Password



Next, visit the `DerivetUI.Web` website. The URL for this website will depend on the port number you entered when creating the website in IIS. Say you used `8089` - in this case you would visit `http://localhost:8089`.



# 3

## MODELING APPROACH

This section briefly describes the approach used to model and bring a disparate set of technologies and services into the same framework.

DER-VET is an optimization-based model and every technology, service, and feature in the tool serves to modify or build the constraints and objective function in the optimization problem. There are four essential products that are produced by technologies and consumed by services. These are power, power reservation, energy, and energy reservations. It is the objective of the optimization problem to allocate the resources the technologies provide to the available services in such a way as to maximize the financial benefit of the storage system operator without violating any rules of physical limitations. When size optimization is turned on, the size parameters are converted to optimization variables with their own cost functions and are included in the above optimization. This basic capability can be twisted and repeated to answer sophisticated and nuanced questions about the role of DERs in the energy industry.

### Products

#### Power

Real power is the fundamental objective of most DERs. This product can contribute to most services, like reducing energy costs/increasing energy benefits, deferring asset upgrades, or many others.

#### Power Reservations

Power reservations are how intra-period (shorter than one time step) affects are parameterized and included in the coarse optimization. A power reservation reserves the ability of the storage system to move its power level around its scheduled setpoint, even when it is doing so much faster than the time step is long. In some cases, as with regulation, this power reservation is used during normal operation and will result in some energy transfer. In other cases, like spinning or non-spinning reserves, the power reservation would only be used during contingencies. Because this is a valuation tool and these events tend to be infrequent, contingency services are modeled as never being called. In other words, the DER mix will always be ready to fulfill its obligations but is never called to do so.

#### Energy

Energy is distinguished from power for technologies like energy storage or electric vehicles because the amount of energy they can provide/consume is no longer simply their power ability \* time. For these technologies, the amount of energy they can provide is also limited by their rated energy capacity and their time-dependent state of energy (SOE). If a storage-like technology needs the ability to provide a certain amount of energy in the future, as in the case of backing up a critical load, the energy product will be different from the power product.

Constraints on the energy capability of the DERs are used in many ways to simulate readiness for infrequent events or to mitigate some other modeling assumptions around perfect foresight,

for example. This type of constraint can be used to maintain a minimum state of energy under normal operation so that the storage system is ready to provide backup power during an infrequent grid outage.

### **Energy Reservations**

Energy reservations are dynamic energy readiness constraints. They represent how much the state of energy of a storage system would be different under the worst-case scenarios compared to the “normal” conditions. Energy in either direction can be reserved. For example, when providing regulation down, it is important that a storage system be able to charge enough to satisfy market rules and handle the worst case AGC signal. So, an energy reservation in the up direction is applied. This ensures that the storage system’s state of energy will be low enough when providing regulation down to meet all its requirements. Because the energy reservation depends on how much regulation the system is providing and the nominal energy throughput from all other services, it enables service stacking while maintaining energy obligations.

### **Perfect Foresight and Optimization Window**

Energy storage systems and similar technologies have a state of energy [kWh], also expressed as state of charge [%] that couples every moment in time. When a storage system participates in a service, it could be precluding itself from participating in the future depending on limits placed on the state of energy. As such, knowledge of future conditions (market prices, customer load, solar generation, etc.) is very relevant for realizing the full value of a storage system. In DER-VET, each year of data is partitioned into some number of optimization windows, which is specified by the user or set to be the full year when optimally sizing technologies. If each optimization window is one month long, then DER-VET will run 12 completely independent optimization problems. To de-couple each optimization window, a “target SOC” is collected as a user input. The storage system will return to this SOC at the beginning and end of each optimization window. Breaking the year into shorter optimization windows is important to reduce the solve time of the optimization.

DER-VET by default takes the perfect foresight optimization approach. This means that the optimization is given full knowledge of all information within one optimization window, meaning that the default result is an upper limit on the value a DER mix could achieve under those conditions. Users of DER-VET are encouraged to address this assumption with their own analysis techniques or by utilizing in-built methods, like the persistence or model predictive control methods. Many times, this involves giving the optimization problem different information than is used to evaluate the DER mix’s performance. Some common approaches are outlined below.

#### ***Persistence***

The persistence method involves using data from the past as a stand-in for current or future data. Often, this means using yesterday’s data to generate a charge/discharge profile for today. For example, when trying to calculate day-ahead energy market revenues from a storage system, day-ahead energy prices from yesterday could be used to schedule the charging and discharging for today. But, the actual amount of money transferred will depend on today’s prices, not yesterdays. So, the financial results should be evaluated based on current prices even though the optimization was run using previous-day prices.

This can be achieved in DER-VET by using the in-built method or creating an energy price profile that is shifted according to the persistence method being used and running the tool using that shifted profile. Then, the user can either calculate the financial performance themselves or load the resulting charge/discharge profile into the user-defined constraints and running again.

### ***Model Predictive Control***

Model predictive control is a general term that usually describes a method of on-line control. In planning tools like DER-VET, it is not usually productive to simulate all the details of a specific controller, however, some key features of this type of control can be included.

The model predictive control feature in DER-VET works by using a rolling optimization window. Unlike the default mode, which will partition the year into optimization windows, the model predictive control mode will generate overlapping optimization windows based on the user inputs. Only the first part of each optimization problem is kept and included in results - the latter part is discarded and the optimization window rolls forward by the length of time that was kept. This method restricts the amount of information given to the optimization and forces it to make decisions without the full data set. Each optimization window is still the same perfect foresight optimization as the default case, but was crafted with limited information so is not as optimal.

### ***User-Defined Control***

DER-VET users also can specify exactly what the DERs should do at all times. Through the user-defined constraints, the user can pass the results from their own control simulation and leverage DER-VET's optimization to fill in the gaps.

### **Operational Planning Horizon**

Because of the perfect foresight approach DER-VET employs, it is important to recognize that different services require planning with different lead times. For example, a storage system participating in a day-ahead market needs to have an idea of how it will operate at least 24 hours in advance. But, if that system is also being used to defer an upgrade on a transmission or distribution asset, it will need a fast control loop that responds quickly to changes in load or generation under the overloaded asset. The day-ahead planning process will not have perfect knowledge of what the fast control loop will do because it is still uncertain 24 hours in advance. Ignoring issues surrounding the ownership structures at play, this presents a challenge for a perfect foresight optimization model, which will schedule both operations simultaneously in the same optimization problem.

There is no built-in way to handle this problem in DER-VET beyond conservative planning margins and power reserves.

### **Size Optimization**

Size optimization is handled in DER-VET by converting the size parameters used in a dispatch-only optimization into optimization variables and assigning them a cost function to include in the optimization's objective function. These cost functions must be linear to maintain the optimization problem as a mixed integer linear program. Similarly, the binary variables used in a dispatch-only optimization to prevent concurrent charging and discharging in batteries or to

prevent technologies from operating below their minimum power level (these binary variables are multiplied by the size parameters) must be linearized to be included in a size optimization problem.

In previous optimization-based tools, the number and type of technologies that could be modeled concurrently was very limited. In DER-VET, the number of DERs that can be modeled at a single site is only limited by the solve time of the optimization problem. For large DER mixes, it would be wise to arrive at an approximate size for DERs first, then run DER-VET multiple times with the scenario analysis feature to explore exactly the combination of DER sizes that makes the most sense instead of putting the entire problem in a single size optimization case in DER-VET. Because size optimization increases the solve time of the optimization problem dramatically, it is recommended to avoid this feature for all cases with many controllable DERs or a high time resolution.

### **Multiple-Technology Service Participation**

When multiple DERs are operated to achieve a common set of objectives, DER-VET must calculate the contribution to the DER mix's products (power, power reservation, etc.) from each DER individually. This is because each DER has their own capabilities and set of constraints that could not be captured otherwise. Yet, all the DERs' contributions are provided under a common set of constraints. For example, all DERs must together adhere by the interconnection constraints so the optimization variables for each DER must appear in the same optimization problem. But, each DER participates in each service in a different way with different marginal costs and different capabilities, so a set of related constraints must be reserved for each DER individually. This is achieved in DER-VET by defining fully-constrained optimization variables at the point of interconnection that aggregate important qualities from lower-level optimization variables and constrain them by higher-level considerations.

# 4

## SERVICES

Services in DER-VET are activities the DER mix can do to generate value. Services are broken into two categories – “pre-dispatch services” and “optimization services”. Pre-dispatch services require fixed contributions of power and energy from the DERs to achieve. They are called “pre-dispatch” services because they are treated as constraints in the optimization problem, so are effectively modeled before the operation of the DERs are known. Services relating to reliability or safety are usually in this category. “Optimization services” are those where the economic value of the service and the amount the DERs participate are flexible and ultimately determined by the optimization problem. These services are usually economic in nature, like customer bill reduction services or wholesale market participation.

### **Pre-Dispatch Services**

The pre-dispatch services in DER-VET are used to model some scenario features that introduce some operational requirements that must be satisfied. Before the optimization occurs, a compatibility check is performed on the constraints that model pre-dispatch services to guarantee no infeasibility due to contradictory constraints. If conflicts occur, the user is notified of the infeasibility and the analysis halts.

The following sections elaborate on the pre-dispatch services within DER-VET

- Asset Upgrade Deferral
- Resource Adequacy (Not in Beta)
- Demand Response (Not in Beta)
- Voltage Support / Power Quality (Not in Beta)
- Reliability/resilience
- Custom User Constraints

### ***Asset Upgrade Deferral***

#### **Description**

DERs can be utilized to defer investment in additional distribution or transmission capacity. In DER-VET, the “overloaded asset” is the piece of equipment whose power limits would be violated without the DERs and load modeled in DER-VET. The N-0 reliability case is implemented explicitly, although readiness to cover N-1 contingencies can be modeled using the user-defined constraints. The N-0 case is modeled by assuming the DERs and load are at the same location as the overloaded asset, neglecting any power losses in between the two. Along with a time series deferral load profile, the user inputs a deferral load growth rate, which will escalate the load until the modeled DERs are no longer capable of keeping the power in the overloaded asset within bounds. At this point, the deferral has failed and the upgrade is assumed to have happened, but hopefully the DERs pushed this date back long enough to justify their cost. In years after the deferral failure, the DERs are not constrained to meet the deferral objectives and can operate for economic benefit depending on the other services selected.

In addition to the simple deferral case modeled in DER-VET, connections with the software tools DRIVE and OpenDSS have been developed. These connections allow the user to perform detailed distribution analysis in an external tool and export the results directly to DER-VET and vice versa. This enables the quick and easy workflow already used at EPRI to perform multi-model analysis involving detailed DER and grid models respectively.

### Inputs

Parameters	Description	Type	Length	Range	Units
planned_load_limit	Maximum power flow from the grid	Float	1	$[0, \infty)$	kW
reverse_power_flow_limit	Maximum power flow to the grid	Float	1	$(-\infty, 0]$	kW
Deferral Load (kW)	The time-varying load served by the overloaded asset, not including any loads in the modeled microgrid	Float	n		kW
p_deferral	Economic carrying cost of the overloaded asset upgrade	Float	1		\$/year

### Formulation

The last year the overloaded asset upgrade can be deferred using the input DER mix is estimated. DER-VET achieves this by estimating the minimum power and energy requirements to defer the upgrade for every year of the analysis. This estimate is produced before the optimization by assuming that the DERs are only operated to meet the deferral. In other words, when estimating the power and energy requirements, it is assumed that the DERs will meet the deferral requirements with a minimum of power and energy. This is not optimal dispatch, but is simple, easy to understand, and will give the smallest DER size required to achieve the deferral.

If, for any of the years, the rated power and energy capability of the DER mix is larger than the estimated minimum to meet the deferral, then the asset upgrade can be deferred for the year. A growth rate is applied to the deferral load profile and PV generation to estimate the minimum storage size required to defer the upgrade for the next year. This process repeats until one of the rated power or energy capability is lower than the estimated minimum requirement. This year is the first year the deferral fails.

In addition to the optimization years selected by the user, DER-VET models dispatch on the last year of successful deferral and the first year of failed deferral. If solving an optimization before

the first year of failed deferral, the following constraints are added to make sure the DERs keep the net power at the overloaded asset within bounds:

$$planned\ load\ limit \geq load_{total} + ch - dis - generation_{total}$$

$$reverse\ power\ flow\ limit \leq load_{total} + ch - dis - generation_{total}$$

Otherwise, no additional constraints are added to the system of equations. Note that *ch* & *dis* are optimization variables that represent the charge and discharge power of a storage system.

### Resource Adequacy

#### Description

Resource adequacy is a reliability requirement which ensures that there are sufficient generation and non-generation resources available to meet the forecast peak load along with reserve requirements, generally one to three years ahead. In California, to qualify for system or local area resource adequacy, a storage resource is rated at the maximum output which can be sustained for at least four consecutive hours and be available for at least three consecutive days.

DER-VET constrains the storage system to provide power based on the requirements for fulfilling resource adequacy obligations.

#### Inputs

Parameter name	Description	Type	Length	Range	Unit
<i>dispmode</i>	RA dispatch mode	Bool	1	{0,1}	
<i>idmode</i>	RA peak ID mode. This determines how the operation of the storage system will be constrained.	String	-	{‘Top n events per year/month’, ‘Top n events per month with timing’}	-
<i>days</i>	Number of Peak Events	Int	1	[0, 365]	<i>count</i>
<i>length</i>	Discharge Duration Required for RA Participation	Int	1	[0, 24]	<i>hours</i>
<i>active</i>	RA Active Periods	Bool	<i>n</i>	{0,1}	
<i>RA Capacity Price</i>	RA monthly capacity rate	Float	12	[0, ∞)	$\frac{\$}{kW - mo}$

#### Formulation

In order to meet resource adequacy requirements, the discharge/generation power and/or state of energy is constrained during times determined by the peak ID mode. First, the locations of the

system load peaks are determined based on the ‘idmode’. Then, depending on dispmode, DER-VET restricts either the DER mix’s energy capability or its actual generation power to provide as much qualifying capacity as it can. For storage systems, if the duration of the storage system is less than the input ‘length’, then the qualifying capacity is calculated as the amount of power the system can sustain for the entire length of the event.

idmode	Meaning
‘Peak by year’	The program picks the days in the year with the peak system load and constrains the storage system to discharge during the peak hours of those days. The number of days to consider and the duration of the events are determined by the <days> input and the <length> input respectively.
‘Peak by month’	The program picks the top days in each month and constrains the storage system to discharge during these days. This tends to distribute the events more evenly around the year.
‘Peak by month with active hours’	This is the same as ‘Peak by month’ except the “RA Active (y/n)” column of the timeseries data input file screens which hours will be considered when identifying the monthly system load peaks.

dispmode	Meaning
0	If dispmode is false, then the DER mix’s energy capability will be constrained so that it could fulfill <length> hours of generation during the identified peak system load events but is never actually called to do so.
1	If dispmode is true, the generation power of the DER mix will be constrained so that it is providing power during the identified system load peaks.

The key assumption for resource adequacy when dispmode=1 is that the DER mix has knowledge of its need to participate far enough in advance. This allows the storage system to ensure it has enough state of energy at the beginning of an event to discharge at its qualifying capacity for the entire duration of the event. If these events were to happen with little notice, this condition might be violated based on the other objectives of the storage system.

## ***Demand Response***

### **Description**

This refers to a range of programs which alter the load seen by a utility in response to an economic or reliability-based dispatch instruction. While many program rules are in development, DERs of various configurations can be used for certain DR programs.

A key distinction is made between two kinds of demand response programs – day-of notification and day-ahead notification – and this has large implications for how participation in the program is modeled. Day-ahead notification programs are modeled much like resource adequacy. The DER operator is given ample lead time to charge their storage systems and plan for the demand

response event. This type of program is modeled by constraining the generation power of the DER mix to meet the terms of the demand response program. The other type, day of notification, gives the operator less time to prepare. As such, any participating storage systems need to be ready to fulfill their obligations at any time defined in the program. This type of program is modeled by constraining the state of energy of storage systems and power availability of all DERs to be ready for any possible demand response event, but never actually calling on the DER mix for power.

### Inputs

<b>Parameter name</b>	<b>Description</b>	<b>Type</b>	<b>Length</b>	<b>Range</b>	<b>Unit</b>
<i>days</i>	Number of DR events in a year	Int	1	[0, 365]	<i>Count</i>
<i>length</i>	The duration of one DR event	Int	1	[0, ∞)	<i>Hours</i>
<i>weekend</i>	Is the DR program active on weekends?	bool	1	{0,1}	
<i>program_start_hour</i>	The first hour of the demand response window	Int	1	[0,22]	<i>hour (hour beginning)</i>
<i>program_end_hour</i>	The last hour of the demand response window	Int	1	[1,23]	<i>hour (hour beginning)</i>
<i>day_ahead</i>	Is the storage system operator given notice at least one day in advance?	bool	1	{0,1}	
<i>growth</i>	DR monthly energy rate	Float	1	[0, ∞)	$\frac{\%}{yr}$
<i>DR Months</i>	DR program months	bool	12	{0,1}	

<i>DR Capacity Price</i>	DR capacity price	float	12	[0, ∞)	\$/kW-mo
<i>DR Energy Price</i>	DR energy price	Float	12	[0, ∞)	\$/kWh

## Formulation

There are two ways to define the window during which a demand response event could happen. The first is with a program start hour and its corresponding program end hour. The second is with a program start hour and a length. The length option will be used if program end hour is left empty. For day-ahead notification programs, DER-VET will find the system load peaks in the demand response window and for day-of notification programs, DER-VET will make sure the DER mix has enough power and energy capability to be ready for the entire DR window.

The demand response window is also sensitive to the “DR Months (y/n)” column in the monthly data input file. This column allows the user to turn off participation in demand response during some months of the year.

The value of demand response is calculated based on the power capacity committed to the program and the energy that ends up being delivered for demand response. In the day-of notification case, no energy is actually delivered for demand response, so no energy payment is assessed. In this case, the entire value should be captured by the capacity payment.

## **Voltage Support / Power Quality**

### Description

Voltage support is the ability to produce or absorb reactive power to maintain a specific voltage level under both steady-state and post contingency operating conditions subject to the limitations of the resource’s stated reactive capability. Voltage support is typically provided by generators but can also be provided by transmission devices such as static VAR compensators or inverter-based technologies. Some DERs can be used to support voltage and provide reactive power.

### Inputs

<b>Parameter name</b>	<b>Description</b>	<b>Type</b>	<b>Length</b>	<b>Range</b>	<b>Unit</b>
<i>inv_max</i>	Max apparent power rating of the inverter used for voltage support	float	1	[0, ∞)	VA
<i>price</i>	Yearly Voltage Support Cost Avoided	Float	1	[0, ∞)	\$

## Formulation

Some apparent power capacity in the inverter is reserved to be available for reactive power support. The apparent power flow through the inverter is constrained to be within its limits, including the real power being produced/consumed by the DERs.

### **Backup**

#### Description

DERs can provide backup power to critical loads. For example, in the aftermath of natural disasters when an entire region might go out of power, DERs can provide backup power to traffic lights, schools, hospitals, supermarkets, and gas stations to maintain basic functions. The scheduling of the device for this purpose can require that a minimum energy capability is maintained during normal operation so it is ready for an emergency. DER-VET goes a step further and allows the user to reserve energy capability for backup power on a month-to-month basis. This allows the DER mix to use its full energy capability for other purposes during months when outages are unlikely or serving the load is not critical.

#### Inputs

<b>Parameter name</b>	<b>Description</b>	<b>Type</b>	<b>Length</b>	<b>Range</b>	<b>Unit</b>
<i>Backup Energy</i>	Monthly Backup Energy Reserved	Float	12	$[0, \infty)$	<i>kWh</i>
<i>Backup Price</i>	Monthly Backup Power Cost Avoided	Float	12	$[0, \infty)$	\$

## Formulation

The energy capability of the DER mix is constrained to be at least some minimum level for all months. This means that the DER mix will always have an energy capability high enough that it could provide the requested backup energy in the event of an outage. However, this reduces the potential of the DER mix to generate economic benefit because it cannot use as much of its rated energy capability for economic value streams, which is why the amount of energy reserved for backup can be changed monthly.

### **Custom User Constraints**

#### Description

User-defined constraints allow the user to manipulate the allowed state of the DER mix at every time step. This extremely powerful feature is useful for modeling services that are not explicitly included in DER-VET, handling specific contractual obligations, or any number of other unforeseen purposes.

#### Formulation

Any columns in the input time series CSV that match one of the six possible user constraints will be applied. For storage, they are labeled: *ene\_min*, *ene\_max*, *ch\_min*, *ch\_max*, *dis\_min*, and *dis\_max*. Similar variables are included for each controllable DER. Each of these columns is strictly positive and has units of kW or kWh. It is possible to apply user-defined constraints that

conflict with other constraints, such as the physical limits of the storage system or those applied by other services. In the case of conflicts, the program will not run.

## **Optimization Services**

The dispatch optimization takes as inputs the DER mix's technical parameters, operating constraints, prices for ISO market services, and tariff rates if the system is located behind the meter, to produce an operational profile that maximizes the combined service value. The operation revenue optimization is formulated as a mixed integer linear optimization problem.

The following sections elaborate on the dispatch services within DER-VET:

- Retail Energy Time Shift
- Retail Demand Charge Reduction
- Spinning Reserves
- Non-spinning Reserves
- Frequency Regulation
- Day Ahead Energy Time Shift
- Load Following

### ***Retail Energy Charge Management***

#### **Description**

Time-of-use (TOU) utility rates offer a variable rate for energy consumption different times of day, to better reflect the marginal cost of supplying electricity. For utilities which offer TOU rates, DER-VET can be used to evaluate the customer benefits of shifting load from high-price times to low-price times with storage or using DERs to offset load. This can be paired with a no-export constraint to keep the DERs from generating more power than is consumed by the load in real time.

There are other variants on TOU rates. Real-time pricing refers to retail rates which are consistent with actual real-time wholesale energy prices and these should be modeled in DER-VET as wholesale day ahead energy time shift. DER-VET can be used to evaluate whether different variants on TOU rates correspond to optimal utilization of storage resources, and whether some variants are more supportive of optimal multiple-use applications.

#### **Inputs**

*See Retail Tariff section under Inputs for more information.*

#### **Formulation**

Based on the information from the retail tariff, the retail energy price for each timestep is calculated. The series of prices saved as  $p_{retail}$ .

The objective of retail energy charge management is to use the DERs to buy energy (charge) when the price is low, so that less energy is bought when the price is high. Recall that  $ch_t$  and  $dis_t$  are optimization variables that represents the power dispatch of a storage system and  $gen_t$  are the generation at time  $t$ .

$$\min_{ch,dis} ETS = \min_{ch,dis} \sum_t p_{retail} \cdot (load_t - dis_t + ch_t - ac_{gen_t} - dc_{gen_t})$$

There are no power or energy constraints associated with taking part in retail energy charge management.

### **Retail Demand Charge Reduction**

#### Description

This refers to a service offered by DERs or other measures to reduce the demand charge portion of a customer's electric bill. A demand charge is a charge levied proportionally to the peak customer demand each month. They can take several structures, including time-related charges associated with demand during particular hours of the month and/or season, and facilities-related charges which are assigned to the highest demand hours in the month or other billing cycle.

#### Inputs

See *Retail Tariff* section under *Inputs* for more information.

#### Formulation

DER-VET assumes that demand charges are billed monthly. There can also be a facilities related demand charge component, which is independent of time.

The objective of demand charge management is to minimize the peak load drawn by the customer during the intervals of time when demand charges apply. This results in minimizing the total demand charge in an electrical bill. An electrical bill's demand charge is calculated by first determining the maximum net power seen behind the meter during days and hours that a billing period applies. That maximum net power is then multiplied by the demand rate corresponding to the billing period. Each billing period within the month being optimized is considered and summed.

Let *demand\_rate* denote the set of demand rates, *b*, for each billing period and *t(b)* denote the set of times when the demand rate, *b*, applies. Recall that *ch<sub>t</sub>* and *dis<sub>t</sub>* are optimization variables that represents the power dispatch of the storage system.

$$\min_{ch,dis} DCM = \min_{ch,dis} \sum_{b \in \text{demand\_rate}} b * \max(load_i - dis_i + ch_i - ac_{gen_i} - dc_{gen_i} \quad \forall i \in t(b))$$

There are no power or energy constraints associated with taking part in retail demand charge reduction.

## Spinning Reserves

### Description

Spinning Reserves are generation capacity that is already operating and synchronized to the system that can increase or decrease generation within 10 minutes.

Spinning reserve is utilized primarily to protect against contingencies, notably unplanned outages of major facilities such as transmission lines or generators. Spinning Reserve is acquired from units that are synchronized and can provide full awarded capacity in 10 minutes. When dispatched, the resource must be capable of sustaining its awarded capacity for 30 minutes. Payments are for capacity reserved (\$/MW).

### Inputs

Parameter name	Description	Type	Length	Range	Unit
<i>SR Price</i>	Price signal for providing spinning reserves	Float	<i>n</i>	$[0, \infty)$	$\frac{\$}{kW}$
<i>duration</i>	How much stored energy is required per unit of offered spinning reserves?	float	<i>l</i>	$[0, \infty)$	hours

### Formulation

A DER providing spinning reserves is modeled to reserve its awarded power capacity and corresponding energy capability for the awarded hours. Additional optimization variables must be introduced to represent the energy storage system's capacity to provide spinning reserves.

Optimization Variables	Description	Type	Length	Unit
<i>sr_d</i>	Capacity to provide spinning reserves by discharging	Float	<i>n</i>	<i>kW</i>
<i>sr_c</i>	Capacity to provide spinning reserves by reducing charging	Float	<i>n</i>	<i>kW</i>

Objective function:

$$\text{Spinning Reserves} = \min_{sr_d, sr_c} - \sum_t p_{sr}(sr_{c_t} + sr_{d_t})dt$$

To fulfill spinning reserve requirements when called, the ability to adjust the scheduled power level of the DER mix is guaranteed by the optimization. By reserving the ability to change its power capacity, the DER mix makes sure that, when called for spinning reserve, it will be able to reduce its charging power and increase its discharging/generating power based on the amount of spinning reserves it is providing and sustain this for the duration required by the market's rules.

## Non-Spinning Reserves

### Description

Non-spinning reserves is an ancillary service market product that consists of off-line generation that can be ramped up to capacity and synchronized to the grid in less than 10 minutes (in CAISO) when responding to a dispatch signal.

Similar to spinning reserve, non-spinning reserve is also used to protect against contingencies. Resources must be started (if needed) and synchronized with the full award available in 10 minutes. Hence, the eligible non-spinning reserve capacity is measured as the Start-up time (mins) + Operating Reserve ramp rate (MW/min) × 10 minutes. Energy production must be capable of being maintained for some duration, such as 30 minutes. For most storage technologies, the start-up time of the unit is minimal. There are therefore no operational difference for a storage asset to participate in spinning reserve and non-spinning reserve.

### Inputs

Parameter name	Description	Type	Length	Range	Unit
<i>NSR Price</i>	Price signal for providing non-spinning reserves	Float	$n$	$[0, \infty)$	$\frac{\$}{kWh}$
<i>duration</i>	How much stored energy is required per unit of offered non-spinning reserves?	Float	$1$	$[0, \infty)$	hours

### Formulation

In DER-VET, a DER providing non-spinning reserve is modeled to reserve its awarded capacity for the awarded hours. Additional optimization variables must be introduced to represent the DER mix's capacity to provide spinning reserves.

Optimization Variables	Description	Type	Length	Unit
$nsr\_d$	Capacity to provide spinning reserves by discharging	Float	$n$	$kW$
$nsr\_c$	Capacity to provide spinning reserves by reducing charging	Float	$n$	$kW$

$$Non\text{-}Spinning\ Reserve = \min_{nsr\_d, nsr\_c} - \sum_t p\_nsr (nsr\_c_t + nsr\_d_t) dt$$

To fulfill non-spinning reserve requirements when called, the ability to adjust the scheduled power level of the DER mix is guaranteed by the optimization. By reserving the ability to change its power output, the DER mix makes sure that, when called for spinning reserve, it will be able to reduce its charging power and increase its discharging/generating power based on the amount

of non-spinning reserves it is providing and sustain this for the duration required by the market’s rules.

### **Frequency Regulation**

#### **Description**

Frequency Regulation (or just “regulation”) ensures the balance of electricity supply and demand at all times, particularly over time frames from seconds to minutes. When supply exceeds demand the electric grid frequency increases and vice versa. It is an automatic change in active power output in response to a frequency change. It is required to maintain the frequency within statutory and operational limits.

The CAISO market has several participation models for providing Regulation, which are relevant to different storage technologies. A pumped storage plant would be operated similarly to a conventional generator, with the unit following the regulation signal around a dispatch operating point. Other types of storage technologies, such as batteries, are operated differently because they follow the signal up and down, and can use both charging and discharging modes without transition times, thus amplifying the regulating range. There are two market participation models for these resources: the non-generator resource model (NGR) and the NGR with regulation energy management (NGR-REM) model. In the NGR case, the resource operator manages state of charge through bids or self-management, and the resource can provide Regulation and other services; in the NGR-REM case, the CAISO manages state of charge, but the resource can only provide Regulation. Because the REM case disallows stacking services and requires no operational decision-making, it is not modeled in DER-VET.

#### **Inputs**

<b>Parameter name</b>	<b>Description</b>	<b>Type</b>	<b>Length</b>	<b>Range</b>	<b>Unit</b>
<i>kd</i>	Average K down	Float	1	[0,1]	$\frac{kWh}{kW \cdot hr}$
<i>ku</i>	Average K up	Float	1	[0,1]	$\frac{kWh}{kW \cdot hr}$
<i>Combined Market</i>	Flag for combine market	Bool	1	{0,1}	-
<i>Reg Up Price</i>	Price signal for providing regulation up	Float	<i>n</i>	[0, ∞)	$\frac{\$}{kW}$
<i>Reg Down Price</i>	Price signal for providing regulation down	Float	<i>n</i>	[0, ∞)	$\frac{\$}{kW}$
<i>FR Price</i>	Price to provide regulation in a combined market	Float	<i>n</i>	[0, ∞)	$\frac{\$}{kW}$

Note that the K values represent the small ebb and flows of power that cause frequency to increase or decrease, which happen at a time scale lower than DER-VET models.

## Formulation

DER-VET does not model regulation dispatch explicitly. Rather, it uses a parameterized model to determine the effect of providing regulation on the DER's state across a whole time step. Like the spinning and non-spinning reserves services, the ability to change the system's power output is reserved for regulation, ensuring that the DER mix will always be able to fulfill its obligations.

The objective of frequency regulation is to maximize the revenue obtained from taking part in the regulation market. Because regulation in the up direction and regulation in the down direction can both be provided by modifying the charge or discharge/generation power, regulation up due to charging needs to be distinguished from regulation up due to discharging and regulation down due to charging needs to be distinguished from regulation down due to discharging for storage systems. Disaggregating these optimization variables allows the model to faithfully track energy transfers and their impact on the storage system's state of energy and the DER mix's state as a whole.

Optimization Variables	Description	Type	Length	Unit
<i>regu_d</i>	Capacity to regulate up by discharging	Float	<i>n</i>	<i>kW</i>
<i>regu_c</i>	Capacity to regulate up by charging	Float	<i>n</i>	<i>kW</i>
<i>regd_d</i>	Capacity to regulate down by discharging	Float	<i>n</i>	<i>kW</i>
<i>regd_c</i>	Capacity to regulate down by charging	Float	<i>n</i>	<i>kW</i>

### Frequency Regulation

$$\begin{aligned}
 &= \min_{regu_d, regu_c, regd_d, regd_c} - \sum_t (regu_c_t \\
 &+ regu_d_t)(p_{regu_t} + p_{da_t} \cdot kru_{avg} \cdot dt) \\
 &- \sum_t (regd_c_t + regd_d_t)(p_{regd_t} + p_{da_t} \cdot krd_{avg} \cdot dt)
 \end{aligned}$$

Frequency regulation impacts the state of energy of a storage system in two ways. First, providing regulation will adjust the state of energy of the storage system through unbalanced regulation signals and roundtrip efficiency losses. Second, the storage system needs to have enough headroom and footroom in its state of energy to handle the worst, most unbalanced regulation signal according to the market rules. This means that the storage system cannot be close to fully charged when it is providing regulation down and cannot be close to fully discharged when providing regulation up. How much headroom/footroom is required depends on how much regulation the storage system is offering and the duration requirement for regulation, which is collected as an input.

Regulation modifies the state of energy of the storage system according to the following equation.

$$E_{FR,t} = krd\_arg(regd\_d_t + regd\_c_t \cdot \eta) dt - kru\_arg(regu\_d_t + regu\_c_t \cdot \eta) dt$$

And, to provide some amount of regulation, the storage system must have energy headroom ( $\bar{E}$ ) and footroom ( $\underline{E}$ ), defined by the equations below.

$$\bar{E} = krd\_max(regd\_d_t + regd\_c_t \cdot \eta) dt - kru\_min(regu\_d_t + regu\_c_t \cdot \eta) dt$$

$$\underline{E} = krd\_min(regd\_d_t + regd\_c_t \cdot \eta) dt - kru\_max(regu\_d_t + regu\_c_t \cdot \eta) dt$$

For combined markets, the following apply in addition to the above equations. In this case, DER-VET will read the “FR Price” column instead of either of the “Reg Up Price” or “Reg Down Price” Columns.

$$p\_regu_t = p\_regd_t = \frac{p\_fr_t}{2}$$

$$0 = (regd\_d_t + regd\_c_t) - (regu\_d_t + regu\_c_t)$$

### **Day Ahead and Real Time Energy Market Participation**

#### **Description**

Energy is defined as injections and withdrawals of real power (MWh) at specified locations and in defined time intervals in a wholesale market or a utility dispatch. These locations can be particular busses for injections or, for withdrawals, particular busses (for storage) or aggregations of busses (for retail load).

The energy product is generally provided by DERs either by participating in the energy markets only, to provide energy time-shifting or generating bulk energy, or by jointly providing energy with other services. Energy time-shift or arbitrage is not a market product, but is rather a primary application of storage technologies within the energy markets or in response to time-varying retail rates (see further discussion below). Energy time-shift value is typically understood as the minimum market value for a storage resource, with all other services implying additional value by jointly providing other services

For storage, energy market participation is defined as charging a storage resource during intervals with low (or negative) energy prices and discharging the storage resource during intervals with high energy prices. Energy time-shift is conducted when there are positive net energy market revenues due to charging and discharging net of roundtrip efficiency losses and the opportunity cost of not providing other services is low enough.

For generation resources, energy market participation involves generating energy when the price of energy is high enough to overcome the costs of generating that energy using the DER and the opportunity costs of not providing other services.

## Inputs

Parameter name	Description	Type	Length	Range	Unit
<i>DA Price</i>	Day Ahead energy price signal	Float	<i>n</i>	[0, ∞)	$\frac{\$}{kWh}$

## Formulation

Similar to retail energy charge management, the objective of real time and day ahead energy market participation is to use the energy DER mix to buy energy when the price is low and sell energy when the price is high. Recall that  $ch_t$  and  $dis_t$  are optimization variables that represents the power dispatch of the storage system and  $gen_t$  is the generation power of generators at time  $t$ . The day ahead energy market participation objective is defined below.

$$DA\ ETS = \min_{ch,dis} \sum_t p_{da} \cdot (load_t - dis_t + ch_t - ac_{gen_t} - dc_{gen_t})$$

## Valuation Perspectives

This section describes the valuation perspectives available in DER-VET for DERs. The valuation perspectives follow the California Standard Practice Manual in laying out the relevant components in Participant Cost Test, Total Resource Cost Test, Ratepayer Impact Measure, and Program Administrator Cost Test.

- **Avoided Costs**  
Directly avoided costs include wholesale energy, generation capacity, transmission and distribution infrastructure deferral, and distribution losses. System avoided costs that are sometimes included in cost test assessments but not included here include avoided ancillary services (we include market revenues for DERs from ancillary service participation but not any avoided costs), wholesale price impacts, avoided startup or cycling costs from thermal generators, and any values sometimes included for societal cost tests including avoided greenhouse gas emissions, avoided criteria pollutants, or avoided land and water impacts.
- **Market Revenues**  
Market revenues include ancillary services (frequency regulation, spinning reserves, non-spinning reserves), day-ahead energy market revenues, real-time energy market revenues, and generation capacity payments.<sup>1</sup>
- **Bill Savings**  
Bill savings revenues include reduced energy and demand charges achieved through DER dispatch.

<sup>1</sup> Market revenues and energy and capacity avoided costs are calculated using the same methodologies in StorageVET.

## **Service Compatibility**

This section describes value stacking, one of the primary objectives of DER-VET, how DER-VET achieve value stacking by considering several types of compatibility, and provides examples of feasible value stacking in DER-VET.

The available services for a DER project may vary in terms of location and ownership. DER-VET models service availability in terms of these specifications through compatibility matrices. These matrices map locations and ownership to compatible services.

## ***Value Stacking***

Value stacking refers to the aggregated values a DER mix providing a combination of services can bring. Since each service has its own requirements on the capacity, energy, and availability, a DER mix cannot provide all the services all the time. In DER-VET, value stacking is achieved by ensuring the DER mix is physically capable of providing all stacked services concurrently but allows the users to combine services that may not meet current regulatory standards.

# 5

## TECHNOLOGIES

### Battery Energy Storage

The battery model employed by DER-VET uses three variables to characterize the state of the system – charge power (*ch*), discharge power (*dis*), and state of energy (*ene*). Two binary variables are also employed to ensure that the storage system does not concurrently charge and discharge and to handle minimum power requirements. These binary variables indicate whether the storage system is charging (*on\_c*), discharging (*on\_d*), or neither.

The state of energy of the battery at a given time is defined as the amount of AC energy you would get out if you were to discharge the batteries completely at full power. This definition means that charging power and discharging power will modify the state of energy of the storage system differently via the following equation.

$$\Delta SOE = [\eta * ch - dis] * dt$$

Where  $\eta$  is the roundtrip efficiency of the storage system and *dt* is the time resolution of the data.

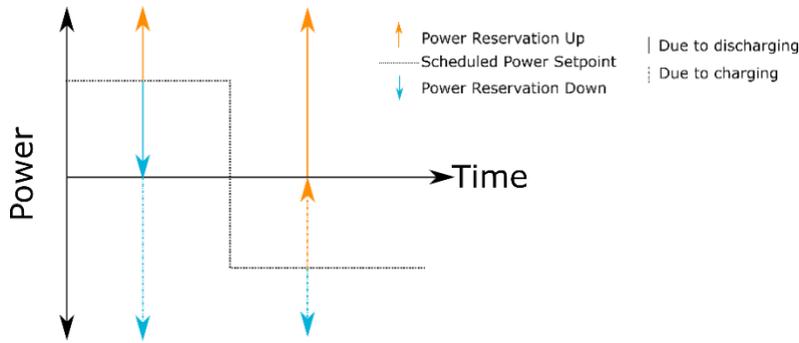
Other things can modify the state of energy of the battery, though. These include self-discharge ( $\Delta SOE = -SOE * \frac{SDR}{100} * dt$  where SDR is the self-discharge rate of the battery [%/hr]) and power use from intra-period cycling such as for regulation.

### Startup cost

The user can enter a startup cost, which will penalize the storage system every time it goes from an off state to an on state.

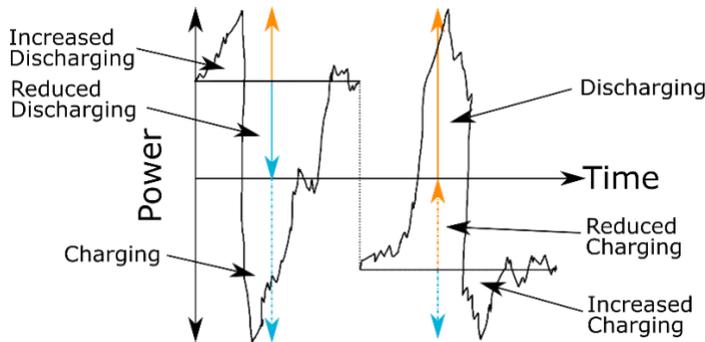
### Power reservation stacking

Recall that power reservations reserve the ability to change the power level of the battery within the time step from what it is scheduled to provide across the entire time step. In the case of regulation, which actively charges and discharges the battery during normal operation, this power reservation will also result in an energy transfer. The storage system must be able to actually supply any power that is reserved, so the combination of reserved power and the scheduled power in the battery cannot exceed the capabilities of the battery. A hypothetical case showing two time steps is shown in Figure 5. In each case, the entire power capacity of the storage system is reserved. In the first time step, the storage system is scheduled to discharge at a constant power over the time step, so can only make a small amount of power reservation available in the up direction. In the second time step, the system is scheduled to charge.



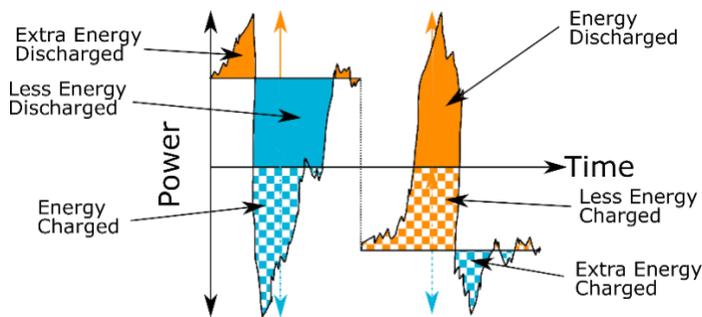
**Figure 5: Power Reservation Scheme**

If the power reservations are for a service like regulation, this power reservation will actively modify the actual power output of the storage system during normal operation. A very hypothetical, unrealistic case of this is shown in Figure 6. In Figure 6, the solid line shows the actual power profile of the storage system in response to the scheduled power (dotted line) and power reservations (colored arrows). This actual operation will modify how much energy cumulatively enters and leaves the battery, which will modify its state of energy over time.



**Figure 6: Hypothetical Actual Power Generation Within Time Step in Response to Power Reservations**

The amount the state of energy will be different from the schedule is shown by the shaded areas below. Because charging and discharging impact the state of energy differently, the power reservations for regulation up due to charging, regulation up due to discharging, regulation down due to charging, and regulation down due to discharging need to be kept separate.



**Figure 7: Difference in SOE Between Scheduled and Actual Case**

## Energy reservation stacking

Energy can also be reserved to ensure no limits will be reached under worst-case conditions or to satisfy market rules. Figure 8 shows a hypothetical case where a storage system follows a similar charge-discharge profile as in Figure 5. In the first time step, the storage system discharges and reserves energy in both directions. At the end of the first time step, the state of energy is as low as it can be while still maintaining enough buffer to handle the worst case scenario. This means that the storage system could not offer any more of a service that requires an energy reservation in the down direction during time step 1 without reducing its scheduled discharge power.

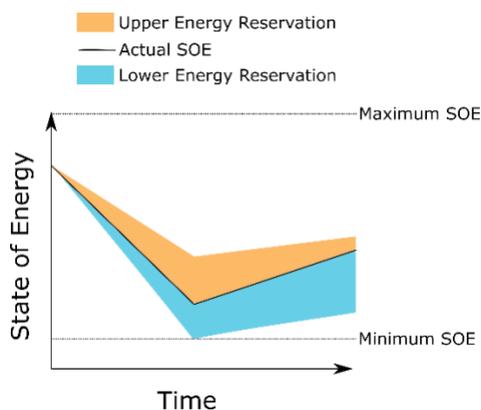


Figure 8: Energy Reservations

## Solar

The “PV” technology, which represents any intermittent generation, has an parameter called “loc” that determines whether the any storage also present is AC-couple or DC-coupled.

If it is AC-coupled, the solar generation is limited only by the solar availability and its own power limits if no upstream constraints apply. If it is DC-coupled, then the combination of the solar generation plus the storage cannot exceed the inverter limit. By default, DC-coupled storage is still allowed to charge from the grid, although this ability can be turned off or on using the grid\_charge parameter under the PV technology.

DC-coupled storage could also be modeled by configuring user-defined constraints to limit the solar generation + battery power to be under the inverter limit and possibly the maximum charge power to be below the solar generation.

## Compressed Air Energy Storage (CAES)

CAES is modeled very similarly to battery energy storage with a few key distinctions.

1. CAES is modeled to be able to both charge and discharge at the same time
2. CAES consumes fuel when discharging, which is penalized in the optimization.
3. CAES has an energy ratio (kWh of electricity in/kWh of electricity out) of greater than one due to its fuel consumption.

### **Internal Combustion Engine (Diesel, ICE)**

Internal combustion engines are modeled in DER-VET as consuming fuel and producing real power. They are not used to provide ancillary services or participate in demand response programs. The optimization will decide to operate internal combustion engines when the variable costs (variable O&M + fuel) are lower than the value of energy.

# 6

## INPUTS

### Model Parameters

#### *Description*

The **Model\_Parameters\_Template\_DER.csv** (MP) file is the recommended format to input the user given parameters. The CSV file is converted to an XML format which is then parsed by our input class and distributed to the different section of the program. There are currently 107 input options.

#### *Operation*

The top of the MP file has the column names: [Tag, Key, Value, Unit, Type, Allowed Values, Sensitivity Parameters, Coupled, Description, Active, Sensitivity Analysis, Options/Notes].

Description of the function of each column in the **Model\_Parameters\_Template\_DER.csv**:

- **Tag:** Relates what group (service, Storage, etc.) the input belongs with. In Figure X, looking at the green circle we see the Tag: DR, which means that following information in the row is for an input relating to the Demand Response pre-dispatch service.
- **Key:** the key is the input variable name, the names are not always clear, so it's best to check the **Description** column to get clarify what the parameter is for.
- **Value:** The value column is where the user input value is given.
- **Unit:** the unit column displays the unit that the code is expecting, for example DR's cap input has its unit in "kW" so all internal code will treat any input given as kW. This column should not be modified, it's main function is to display what unit the program is expecting for the given input.
- **Type:** the type column displays the programmatical type of the input. The code will be expecting all inputs to be of this type and will give an error if the input does not match. For example: RA's max input has a type of float, which means if given a string like 'Day' that cannot be converted, an error will be returned. Internally the code will be converting the input from a String to the given type, so an integer input of 1 is valid as it would be converted to 1.0 in the case of the type being a float. This column also should not be modified.
- **Allowed Values:** This designates the range of valid values that would be allowed. It is currently not used by the code.
- **Sensitivity Parameters:** Sensitivity is where multiple values of an input can be given. The input should be in the format: [value\_1, value\_2, value\_3]. Sensitivity is an easy way of running many scenarios with the same structure (services, storage), but different input values.
- **Coupled:** coupled ties different parameters together if sensitivity analyses is active for both services. For example if two services have sensitivity on and both have 3 values in a list ([A\_1, A\_2, A\_3] and [B\_1, B\_2, B\_3]), 9 scenarios are run ([A\_1, B\_1], [A\_1,

B\_2], [A\_1, B\_3], [A\_2, B\_1], etc.) , but if the two were coupled together only 3 scenarios are run: ([A\_1, B\_1], [A\_2, B\_2], [A\_3, B\_3]). The format for coupled should be: (key\_1, key\_2, key\_3). More than two inputs can be coupled together.

- **Description:** This gives a description of the input parameter. It’s not currently used by the code.
- **Active:** Active tells the program if a given service or technology is active for the scenario. This can be seen in the red circle from Figure X. The active tag is only asked for the beginning of a new tag. The green and red circles are on the same row in figure X and their row is the first row for the DA tag. All other inputs with the DA tag will have a “.” For the active row, this is because whether DA is active was set by the first row with a DA parameter. There are three Tags that should always be active: Storage, Scenario and Finance.
- **Sensitivity Analysis:** this designates whether the parameter will be included for sensitivity analysis. So, if Sensitivity has some values: [value\_1, value\_2, value\_3], but the analysis tag is set to ‘no’, then those values will not be included in the run. The three blue circles in Figure X show all the column sections related to sensitivity analysis.
- **Options/Notes:** This column is ignored by the program and can be used for any personal notes.

Tag	Key	Value	Units	Type	Allowed	Sensitivity	Coupled	Descriptio	Active	Sensitivi
Scenario	monthly_c	.\Data\Mc	N/A	string	valid file	N/A	None	N/A	yes	no
Scenario	time_ser	.\Data\tes	N/A	string	valid file	.\Data\tes	None	N/A	.	no
Scenario	customer	.\Data\tar	N/A	string	valid file	N/A	None	N/A	.	no
Scenario	cycle_lif	.\Data\Ba	N/A	string	valid file	N/A	None	N/A	.	no
Scenario	dt		1 hours	float	(0,1)	N/A	None	Time step	.	no
Scenario	opt_years	2017	year	list/int	the year	N/A	None	which yea	.	no
Scenario	start_year	2017	year	Period	opt_years	N/A	None	first year	.	no
Scenario	end_year	2030	year	Period	opt_years	N/A	None	last year	.	no
Scenario	n	month	hours	string/int	{month,ye	N/A	None	optimizati	.	no
Scenario	incl_site	1	N/A	bool	{0,1}	N/A	None	Flag to inc	.	no
Scenario	incl_sys	0	N/A	bool	{0,1}	N/A	None	Flag to inc	.	no

Figure 9: Example of Model\_Parameters\_Template\_DER.csv

Some additional notes on the MP file. The code that converts the csv is currently finicky, and may not act kindly to manipulation, in the form of rearranging columns, rows or deleting inputs. It may also not properly handle extra white spaces. For example, if a value is given as “value “ this may fail to covert to the proper type and throw an error. So, if an error returns saying “1 is not of type int” then it’s best to check to see if there are extra white spaces in the csv file.

There are a couple inputs that have only a tag and active column, those services or technologies have no unique input parameters and so the system only needs to know if they should be included through the active tag and then will get the needed parameters though parent classes. For example, the Battery tag does not have any unique inputs, it inherits all its parameters from the Storage tag.

## Usage

Setting up your storage system: DER-VET has 2 options for storage systems: A Battery system or a Compressed Air Energy System (CAES). If you wish to run a scenario with a Battery system, the first step is find the row with the Battery Tag, as identified with the green arrow in Figure X+1. Now all the Batteries attributes are under the general Storage tag, so the only concern is to make sure the 'Active' column of the Battery row is set to 'yes', as can be seen with the light green arrow in Figure X+1. CAES has all the same parameters as a general battery, plus one additional parameter unique to the system: 'heat\_rate\_high'. That is why it has a parameter tied to its specific tag. Now once the battery tag is set to active, look to the Storage tag, seen circled on Figure X+1. This is where the parameters for the battery will be given. For example, to set the energy storage charge capacity of the battery we can go to 'ch\_max\_rated' key and set the value. In Figure X+1 we see at the first blue arrow the value is set to 1000. All the parameters with the Storage tag relate to storage system.

	A	B	C	D	E	F	G	H	I	J	K
1	Tag	Key	Value	Units	Type	Allowed V	Sensitivity	Coupled	Description	Active	Sensitivity
30	Results	errors_log_path	Enter abs	N/A	string		N/A	None	Absolute pat		no
31	Battery	name	Battery		string		N/A	None	User defined	yes	no
32	Battery	ccost	0 \$		float	[0, ccost)	N/A	None	Capital Cost		no
33	Battery	ccost_kw	100 \$/kW		float	[0, ccost_k	N/A	None	Capital Cost i		no
34	Battery	ccost_kwh	500 \$/kWh		float	[0, ccost_k	N/A	None	Capital Cost i		no
35	Battery	startup	0 N/A		bool	{0,1}	N/A	None	T of F to inclu		no
36	Battery	fixedOM	0 \$/kW-yr		float	[0, fixedOI	N/A	None	Fixed Operat		no
37	Battery	OMexpenses	0 \$/MWh		float	[0, Omexp	N/A	None	Variable Ope		no
38	Battery	ch_max_rated	2000 kW		float	[0, ch_ma:	N/A	None	Energy Stora		no
39	Battery	dis_max_rated	2000 kW		float	[0, dis_ma	N/A	None	Energy Stora		no
40	Battery	ch_min_rated	0 kW		float	[0, ch_min	N/A	None	Energy Stora		no
41	Battery	dis_min_rated	0 kW		float	[0, dis_mii	N/A	None	Energy Stora		no
42	Battery	ene_max_rated	10000 kWh		float	[0, ene_m	N/A	None	Energy Stora		no
43	Battery	ulsoc	100 %		float	[0, 100] (r	N/A	None	Energy Stora		no
44	Battery	llsoc	5 %		float	[0, 100] (r	N/A	None	Energy Stora		no
45	Battery	rte	85 %		float	[0, 100]	N/A	None	Energy Stora		no
46	Battery	sdr	0 %/hr		float	[0, 99]	N/A	None	Energy Stora		no
47	Battery	soc_target	50 %		float	[0, 100]	N/A	None	The SOC the		no
48	Battery	yearly_degrade	0 N/A		int	[0, 100]	N/A	None	% degradatio		no
49	Battery	incl_cycle_degrade	0 N/A		bool	{0,1}	N/A	None	T or F to inclu		no
50	Battery	cycle_life_filename	.\Data\Ba	N/A	string	valid file p	N/A	None	For our rainf		no
51	Battery	p_start_ch	0 \$		float	[0, p_start	N/A	None	Startup cost t		no
52	Battery	p_start_dis	0 \$		float	[0, p_start	N/A	None	Startup cost t		no
53	Battery	daily_cycle_limit	1 cycles		float	[0, daily_c	N/A	None	Limit the dail		no
54	Battery	hp	0 kW		float	[0, hp)	N/A	None	Housekeepin		no
55	CAES	name	2MW-5hr	N/A	string		N/A	None	User defined	no	no

(Figure X+1: snippet of Model\_Parameters.csv)

## Time Series Data

This input file contains all the data that changes with every time step in the year. This includes all market prices, loads, and non-dispatchable generation. All power fields have units of kW, prices are in \$/kW or \$/kWh.

Datetime (he)	DA Price (\$/kWh)	FR Price (\$/kW)	SR Price (\$/kW)	Deferral Load (kW)	ra_active	regu Price	NSR_Price (kW)	regd_price	System_Load (kW)	Site_Load (kW)	PV_Gen (kW/rated kW)
---------------	-------------------	------------------	------------------	--------------------	-----------	------------	----------------	------------	------------------	----------------	----------------------

**Datetime** (he) is the date and time of the timestep, hour ending, in yyyy-mm-dd hh:mm:ss format.

**DA Price** (\$/kWh) is the energy price on the day ahead energy market in \$/kWh.

**FR Price** (\$/kW) is the frequency regulation price for a combined market in \$/kW. If the regulation market is not combined, as in CAISO, then two columns need to replace this, which are Reg Up Price (\$/kW) and Reg Down Price (\$/kW).

**SR Price** (\$/kW) is the price of spinning reserve in the wholesale market in \$/kW.

**NSR Price** (\$/kW) is the price of non-spinning reserves in the wholesale market in \$/kW.

**PV Gen** (kW/rated kW) is the solar generation in kW/rated kW.

**System Load** (kW) is the load of the ISO

### Monthly Data

This input file contains all the data that changes monthly.

Year	Month	Fuel Price (\$/MillionBTU)	Backup Price (\$/kWh)	Backup Energy (kWh)	DR Months	DR Cap (kW)	DR Cap Price (\$/kW)	DR Energy Price (\$/kWh)	RA Price (\$)
2017	1	10	0	0	0	0	100	20	30
2017	2	10	1000	10	0	0	100	20	30
2017	3	10	1000	10	0	0	100	20	30
2017	4	10	1000	10	0	0	100	20	30
2017	5	10	1000	10	0	0	100	20	30
2017	6	10	1000	10	1	10	100	20	30
2017	7	10	1000	10	1	10	100	20	30
2017	8	10	1000	10	1	20	100	20	30
2017	9	10	1000	10	1	10	100	20	30
2017	10	10	1000	10	0	0	100	20	30
2017	11	10	0	0	0	0	100	20	30
2017	12	10	0	0	0	0	100	20	30

**Backup Price** (\$/kWh) indicates the value in \$/kWh for reserving backup power.

**Backup Energy** (kWh) indicates how many kWh to reserve in that month for backup power if the backup service is selected.

**DR Months** represents if the demand response program is active (1) or not (0) in that month. This is only used if the demand response service is selected.

**DR Cap** (kW) represents the power in kW that will be committed to the demand response program.

**DR Cap Price** (\$/kW) indicates the value in \$/kW for reducing demand during demand response events.

**DR Energy Price** (\$/kWh) indicates the value in \$/kWh for reducing energy consumption during demand response events.

**RA Price** (\$) is the value of resource adequacy for that month. This is only used when the resource adequacy service is selected.

**Retail Tariff**

DER-VET needs the flexibility to handle most of the incredible variety of retail tariffs in existence. Tiered demand rates, overlapping demand charge periods, different time resolutions for calculating demand charges, riders, standby rates, and many other factors make this a challenge. This is an area of development, but the current approach does well in most cases with non-tiered demand charges where the time series data matches the time resolution of the demand charge calculation. In other words, if demand charges are calculated using the peak 30-minute period, then the time step of the data should be 30 minutes.

The current approach is to define a set of ‘billing periods’ where the charges associated with each billing period sum to the total monthly bill. Attributes of each billing period include the start month, end month, start time, end time, weekday/weekend/both, rate, what kind of charge it is, a description of the billing period, and any hours in between the start time and end time that are excluded from that billing period.

The number of billing periods is unlimited, so very complicated tariffs with TOU energy rates, TOU demand charges, overlapping demand charges, and other complicated setups are possible.

Billing Period	Start Month	End Month	Start Time	End Time	Excluding Start Time	Excluding End Time	Weekday?	Value	Charge	Name_optional
1	1	5	1	24			2	0.05323	Energy	
2	1	5	1	24			2	26.75	Demand	
3	6	9	1	24			2	0.05668	energy	
4	6	9	1	24			2	26.75	demand	
5	10	12	1	24			2	0.05323	energy	
6	10	12	1	24			2	26.75	DEMAND	

**Billing Period** is a positive integer that is used to track this billing period and where it applies in the time series data.

**Start Month** [1,12] integer is a numeric representation of the first month that this billing period applies to.

**End Month** [1,12] integer is a numeric representation of the last month that this billing period applies to.

**Start Time** [1,24] integer is the first hour (in hour ending format) that this billing period applies to. At this time specificity at a finer resolution than 1 hour is not supported.

**End Time** [1,24] integer is the last hour (in hour ending format) that this billing period applies to.

**Excluding Start Time** [1,24] integer is the first hour in between Start\_time and End\_time that will be excluded from this billing period.

**Excluding End Time** [1,24] integer is the last hour in between Start\_time and End\_time that will be excluded from this billing period.

**Weekday** [0,2] integer is a numeric representation of whether this billing period applies to weekends (0), weekdays (1), or both (2).

**Value** is the charge to be applied to the time described by the previous entries. If the value is an energy price, then units are \$/kWh. If the value is a demand rate, then units are \$/kW.

Please note that only one energy price can apply to any time step. In the case of overlapping billing periods, the program will take the energy price defined lower down in the tariff data frame. This is an open issue that we are working on. Conversely, multiple demand rates can apply to any time step and the total demand charge for the month will be the sum of all the demand charges in the month.

**Charge** is a string that indicates which type of charge the value is. The only possible values are 'demand' or 'energy.' This is not case-sensitive.

**Name\_optional** string is meant to be descriptive text that can be used when displaying the results so the user can more easily understand the outputs and identify problems. An example might be "Summer On-Peak Demand Charge".

# 7

## OUTPUTS

### CSV Filesa

#### ***adv\_monthly\_bill file***

The bill that will come with the inputted retail tariff. This bill is indexed by month-billing period, which means that every billing period in a month is reported separately.

#### ***demand\_charges file***

A file with only the “Demand Charge Billing Period” column from the time series file. This time will be saved to disk if Demand Charge Reduction is selected as an *active* service.

#### ***dispatch\_map file***

This file is a pivot table of the ESS’s power timeseries array. The days in a year are along the x-axis and the hours in a day are along the y-axis. This file will only show up if there is an ESS included in the analysis.

#### ***monthly\_data file***

All the monthly data is collected in this file. Any data that was given to the model is also saved here and given back to the user. Except for the index, all the columns will be ordered alphabetically.

#### ***npv file***

The file reports the net present value of the cash flows reported in the *proforma* file. These values consider inflation and discount rates of entire life of the project to help identify whether the project adds value over multiple years.

#### ***objective\_values file***

This file will only show up if the user sets the ‘verbose’ tag under the ‘Scenario’ key is true. All the column names follow conventions internal to the code, so it is hard to discern what anything means without diving into the code. It is **not** recommended to use the values reported in this file for analysis. Instead a user should refer to the *proforma* file for this data.

#### ***opt\_results file***

This file will only show up if the user sets the ‘verbose’ tag under the ‘Scenario’ key is true. All the column names follow conventions internal to the code, so it is hard to discern what anything means without diving into the code. The data in this file can be found in the *timeseries* file, but with column names that mean something to the user.

#### ***payback file***

The payback period is the number of years it takes the project to break even. In other words, if you ended the analysis at year x, the sum of all costs and benefits up to that point would be zero. The discounted payback period is also reported. This is the number of years it takes for the NPV of the project to be zero. This number should be higher than the payback period when the

discount rate is  $> 0$ . This number should be the same as the payback period if the discount rate is zero. These outputs are independent from the analysis horizon and in the case of multiple `opt_years`, do not report a payback period.

### ***pro\_forma file***

Each cost and benefit, for every technology and service, is calculated for the years that the dispatch was solved for. There are 3 types of costs and/or benefits you will find in the proforma. The first are 0 for all other years than analysis years (assuming the calculated value was not 0 as well). The second are constant columns, which are constant in real terms for all years within the project lifetime. The last are yearly costs or benefits. The inflation rate is used to escalate the value from `opt_years` to years without a dispatch optimization. The pro forma represents nominal cash flows for each year of the analysis.

### ***simple\_monthly\_bill file***

The monthly bill resulting from the operation of the DERs in question with the inputted retail tariff.

### ***technology\_summary file***

A file that list all the DER in the analysis. It matches the type of technology with the user given name. This should be consistent to the user-given model parameter CSV.

### ***timeseries file***

All the timeseries data is collected in this file. Any data that was given to the model is also saved here and given back to the user. All dispatch data is collected here. Except for the index, all the columns will be ordered alphabetically. The potential column names are listed below, categorized by service and technology type, and then columns in that will always be included.

### ***DER time series results***

The following columns will be included for every **Battery** object that is modelled:

- *BESS: <user given name> Charge (kW)*  
The charging value of the BESS. This is the raw optimization solution value.
- *BESS: <user given name> Discharge (kW)*  
The discharging value of the BESS. This is the raw optimization solution value.
- *BESS: <user given name> Power (kW)*  
The dispatch of the BESS. Negative numbers indicate that the battery is charging, while positive numbers indicate the BESS is discharging.
- *BESS: <user given name> SOC (%)*  
The State of Charge of the BESS – how full is the BESS.
- *BESS: <user given name> State of Energy (kWh)*  
The amount of energy stored in the BESS at the time.

The following columns will be included for every **CAES** object that is modelled:

- *<user given name> Charge (kW)*  
The charging value of the CAES. This is the raw optimization solution value.
- *<user given name> Discharge (kW)*  
The discharging value of the CAES. This is the raw optimization solution value.
- *<user given name> Power (kW)*

The dispatch of the CAES. Negative numbers indicate that the CAES is charging, while positive numbers indicate the CAES is discharging.

- *<user given name> SOC (%)*  
The State of Charge of the CAES – how full is the CAES.
- *<user given name> State of Energy (kWh)*  
The amount of energy stored in the CAES at the time.
- *<user given name> Fuel Price (\$)*  
The price of fuel that was given monthly

The following columns will be included for every **CurtailPV** object that is modelled:

- *PV Generation (kW)*  
This the solution to an optimization variable that represents the actual PV generation of the PV model.
- *PV Maximum (kW)*  
This is the generation profile the user inputted, multiplied by the rated value of the PV system.

The following columns will be included for every **Internal Combustion Engine** object that is modelled:

- *ICE Generation (kW)*  
The total power outputted by the ICE genset
- *ICE On (y/n)*  
A variable that indicated whether or not at least 1 generator in the genset is on
- *ICE P\_min (kW)*  
The minimum power a single genset would be able to discharge
- *ICE Genset P\_max (kW)*  
The power that all the ICE in the genset would be able to discharge if each were running at their maximum.

### **value stream columns results**

The following columns will be included for every **Backup** object that is modelled:

- *Backup Energy Min Added (kWh)*  
The minimum energy that the aggregated energy within the system must have

The following columns will be included for every **Day Ahead Energy Time Shift** object that is modelled:

- *DA Price Signal (\$/kWh)*  
Defines energy charges. The time series price signal that the user inputted.

The following columns will be included for every **Deferral** object that is modelled:

- *Deferral Load (kW)*  
This is the load in front of the asset that needs to be deferred. The user gave this value as an input.

The following columns will be included for every **Demand Charge Reduction** object that is modelled:

- *Demand Charge Billing Periods*  
An array of lists. The list contains the billing periods, from the retail tariff, that apply to the corresponding time step.

The following columns will be included for every **Demand Response** object that is modelled:

- *System Load (kW)*  
The system load profile inputted by the user.
- *DR Possible Event (y/n)*, optional  
An array of Booleans that indicate if there might be a DR event. If this column shows up, then the system operating for preparedness. In other words, the system is prepared in case the event will actually happen, however DER-VET never simulates the event actually happening.
- *DR Discharge Min (kW)*, optional  
The minimum that system should be discharging. If this column shows up, then the system is operating as if the DR event occurs during the times that the constraint is none zero.

The following columns will be included for every **Retail Energy Time Shift** object that is modelled:

- *Energy Price (\$/kWh)*  
The energy charges defined in the retail tariff, as converted into a time series price signal

The following columns will be included for every **Frequency Regulation** object that is modelled:

- *FR Energy Throughput (kWh)*  
The deviation in SOC of a battery expected as a result of providing regulation
- *FR Energy Throughput Up (Charging) (kWh)*  
The portion of the energy throughput that is from regulation up due to charging
- *FR Energy Throughput Up (Discharging) (kWh)*  
The portion of the energy throughput that is from regulation up due to discharging
- *FR Energy Throughput Down (Charging) (kWh)*  
The portion of the energy throughput that is from regulation down due to charging
- *FR Energy Throughput Down (Discharging) (kWh)*  
The portion of the energy throughput that is from regulation down due to discharging
- *FR Energy Settlement Price Signal (\$/kWh)*  
The price that energy is settled at. This was inputted by the user under ‘DA price’
- *Regulation Up (Charging) (kW)*  
The amount bid into the regulation up market that an ESS can provide from charging.
- *Regulation Up (Discharging) (kW)*  
The amount bid into the regulation up market that an ESS can provide from discharging
- *Regulation Down (Charging) (kW)*  
The amount bid into the regulation down market that an ESS can provide from charging.
- *Regulation Down (Discharging) (kW)*  
The amount bid into the regulation down market that an ESS can provide from discharging.

- *Regulation Up Price Signal (\$/kW)*  
The price that one would get per kW for providing regulation up
- *Regulation Down Price Signal (\$/kW)*  
The price that one would get per kW for providing regulation down

The following columns will be included for every **Load Following** object that is modelled:

- *LF Energy Throughput (kWh)*
- *LF Energy Throughput Up (Charging) (kWh)*
- *LF Energy Throughput Up (Discharging) (kWh)*
- *LF Energy Throughput Down (Charging) (kWh)*
- *LF Energy Throughput Down (Discharging) (kWh)*
- *LF Energy Settlement Price Signal (\$/kWh)*
- *LF Up (Charging) (kW)*
- *LF Up (Discharging) (kW)*
- *LF Down (Charging) (kW)*
- *LF Down (Discharging) (kW)*
- *LF Up Price Signal (\$/kW)*
- *LF Down Price Signal (\$/kW)*

\*see Frequency Regulation for column descriptions, just replace ‘FR’ or ‘Regulation’ with ‘LF’

The following columns will be included for every **Non-spinning Reserves** object that is modelled:

- *NSR Price Signal (\$/kW)*  
The price that one would get for providing non-spinning reserves, per kW.
- *Non-spinning Reserve (Charging) (kW)*  
The amount bid into providing non-spinning reserves due to charging.
- *Non-spinning Reserve (Discharging) (kW)*  
The amount bid into providing non-spinning reserves due to discharging.

The following columns will be included for every **Resource Adequacy** object that is modelled:

- *System Load (kW)*  
The system load profile inputted by the user. Is used, with combination with the ‘ID mode’ to determine when RA events will occur.
- *RA Event (y/n)*  
An array of Booleans that indicate if there is an RA event that the system must be ready for.
- *RA Discharge Min (kW), optional*  
Minimum discharge that the system must meet (applies during RA Events). If this column appears, then the RA payment corresponds to the amount of power you are providing.
- *RA Energy Min (kWh), optional*  
Minimum energy that must be stored within our system to meet the RA Event requirement. If this column appears, then the RA payment corresponds to the amount of energy that you could provide.

The following columns will be included for every **Spinning Reserves** object that is modelled:

- *SR Price Signal (\$/kW)*
- *Spinning Reserve (Charging) (kW)*
- *Spinning Reserve (Discharging) (kW)*

\*see Non-spinning Reserves for column descriptions, just replace ‘NSR’ with ‘SR’ or ‘Non-spinning’ with ‘Spinning’

No additional columns are added for every **User Constraint** object that is modelled.

### ***timeseries columns results***

The following columns will always be included:

- *Start Datetime*  
This column serves as the index of the file. The units are in hour beginning.
- *Total Load (kW)*  
This is the site load, if the user includes it in analysis. Otherwise this is zero.
- *Total Generation (kW)*  
The sum of each DER’s generation column.
- *Total Storage Power (kW)*  
The sum of each ESS’s net power
- *Original Net Load (kW)*  
The total load without any DERs. This value serves as the baseline in the cost-benefit analysis module.
- *Net Load (kW)*  
The load with DERs, to be compared with the baseline.

### ***cost\_benefit file***

This file contains a cost-benefit table. The columns of the table are the individual sources or sinks of monetary value come from (taken from the proforma). The cost row is the present value of all negative entries of the same column within the proforma. The benefit row is the present value of all positive entries of the same column within the proforma.

### ***validation file***

This file is only be saved to disk if the user runs a case with verbose case. It contains developer short hand and is not meant for the regular user’s use.

## **Log Files**

### ***Error Log***

Description:

The user can look at this error log file to identify any error or critical warnings that could prevent the case simulation from fully running or producing reasonable results.

How It Works:

The error log file is created after the empty Input class object initializes its attributes with the Schema. It is included inside the results\_filename (Results) folder, which is determined by the location of the parameters filename input.

Error log file name is errors\_log.log, it is overwritten every time the user initializes new Input.

Types of Errors: (updated over further development)

- 1) Input validation:
  - Could not open, read, or find the parameters .csv file
  - Could not convert the input value to the desired type indicated by the Schema
  - Out-of-bound input value
  - Incorrect input types
  - Missing input parameter
  - Attribute error per respective tag
- 2) Other Input Checks outside validation:
  - Time series data and dt parameter have different granularity
  - More than one year of analysis is indicated for size optimization
  - Scenario: Optimization years ('opt\_years') is ahead of the time series data
  - Scenario: One or more of the optimization years does not have any time series data
  - Scenario: end year is before the start year
  - Scenario: site load is not included when DCM or retailTimeShift is active
  - Scenario: start year is after all the optimization years
  - Storage Technology: rated minimum charge is greater than rated maximum charge
  - Storage Technology: installation date is after all the optimization years
- 3) Finances:
  - Storage Technology: Value Error in capital cost while calculating yearly financials
  - Storage Technology: Value Error in fixed or variable operation/maintenance cost while calculating yearly financials
- 4) Scenario:
  - Adding Control Constraints: is not possible when scenario is infeasible and deferral failure analysis is not running
  - Adding Control Constraints: gives Warning to return feasible check when deferral failure analysis is active
  - Optimization Problem: solver error
  - Optimization Problem: gives Warning when non-zero slack variables are found in the solution
  - Optimization Problem: gives Warning when non-zero charge and discharge powers are found in the solution, and if binary formulation is needed.
- 5) Storage Technology:
  - Calculating Control Constraints: has problem when user inputs invalid constraint type
- 6) Battery Storage:
  - Degradation fails to model a feasible scenario when Battery applies degradation



# 8

## REFERENCES

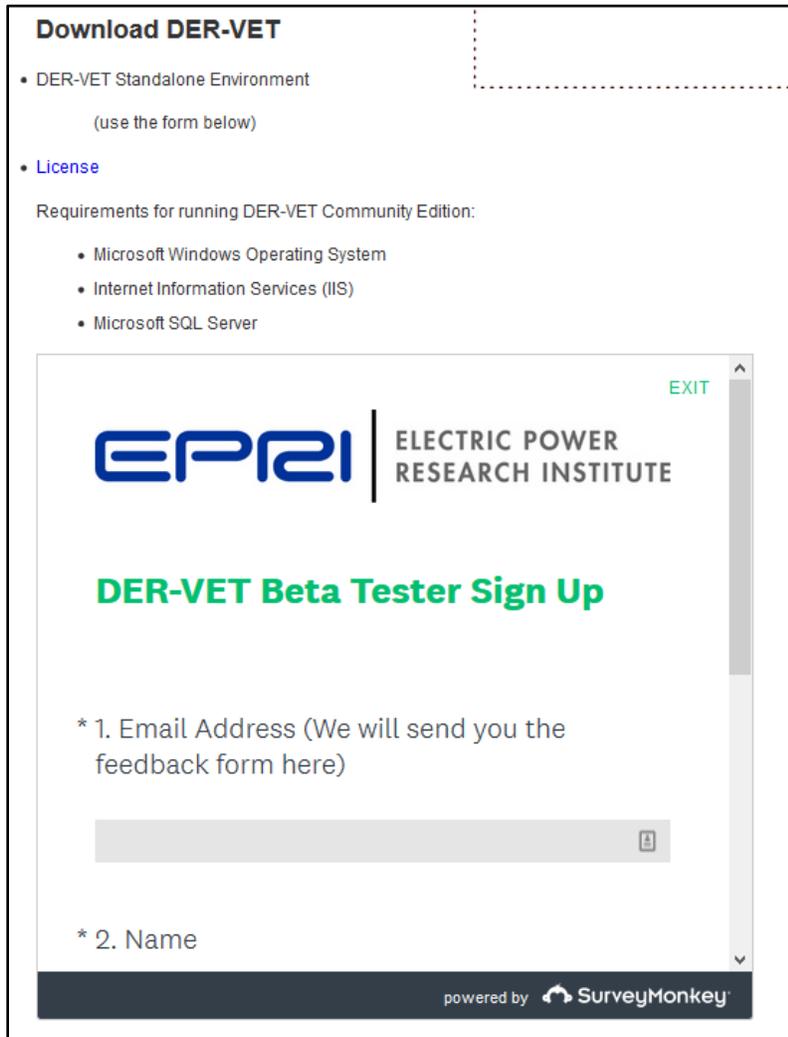
### References

1. B. Kaun, G. Damato, A. Cortes. StorageVET™ V1.0 Software User Guide: User and Technical Documentation for the Storage Value Estimation Tool. Electric Power Research Institute, Palo Alto, CA. December 2016. [online software documentation]  
<https://www.epri.com/#/pages/product/000000003002009357>

# A EXPERT INSTALLATION

## Download DER-VET

DER-VET is available for download at <https://der-vet.com/>. Click the *DER-VET Standalone Environment* link under the Download DER-VET heading. Complete the brief Survey Monkey form. After completion, click the link to download the zipped standalone DER-VET environment for version 0.1.1: `dervet_v011.zip`.



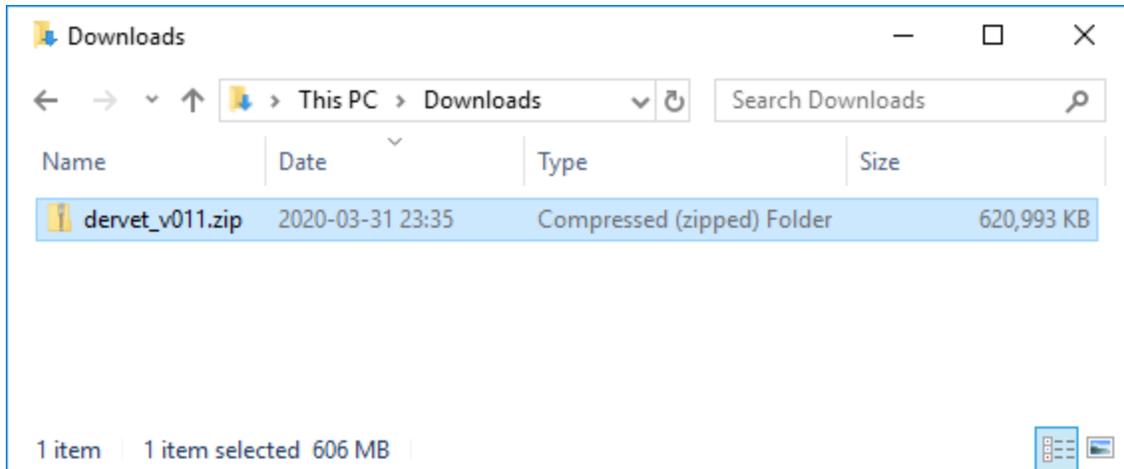
The screenshot shows a web page titled "Download DER-VET". It contains a list of items for download, with "DER-VET Standalone Environment" selected. Below this, there is a note "(use the form below)". A "License" section lists requirements for running DER-VET Community Edition: Microsoft Windows Operating System, Internet Information Services (IIS), and Microsoft SQL Server. A sign-up form for "DER-VET Beta Tester Sign Up" is displayed, featuring the EPRI logo and the text "ELECTRIC POWER RESEARCH INSTITUTE". The form includes an "EXIT" button, a text input field for "1. Email Address (We will send you the feedback form here)", and a text input field for "2. Name". The form is powered by SurveyMonkey.

## Installing DER-VET (Required for GUI AND Command Line Users)

DER-VET can be used in two ways – from the command line and with a graphic user interface (GUI). Using the GUI requires installing the command line version of DER-VET first.

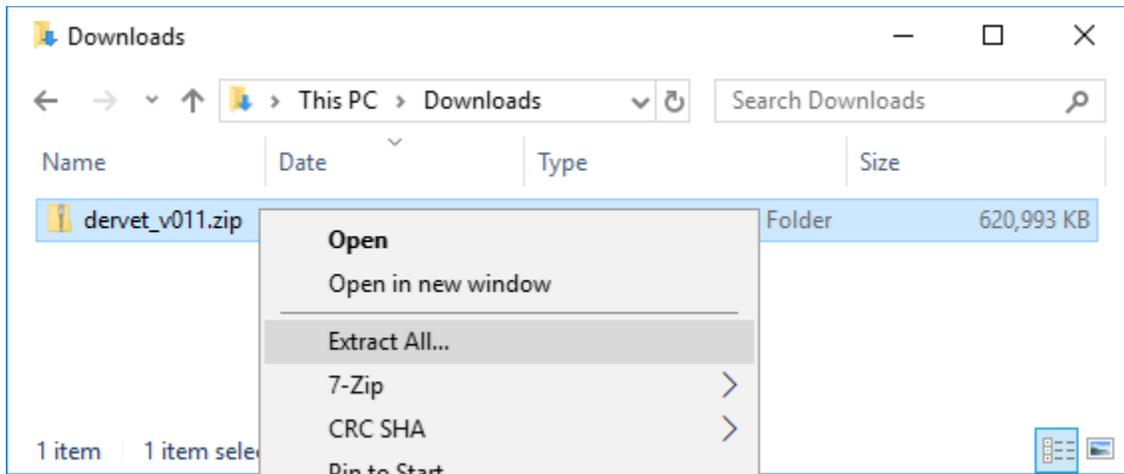
### **Extract the DER-VET Environment**

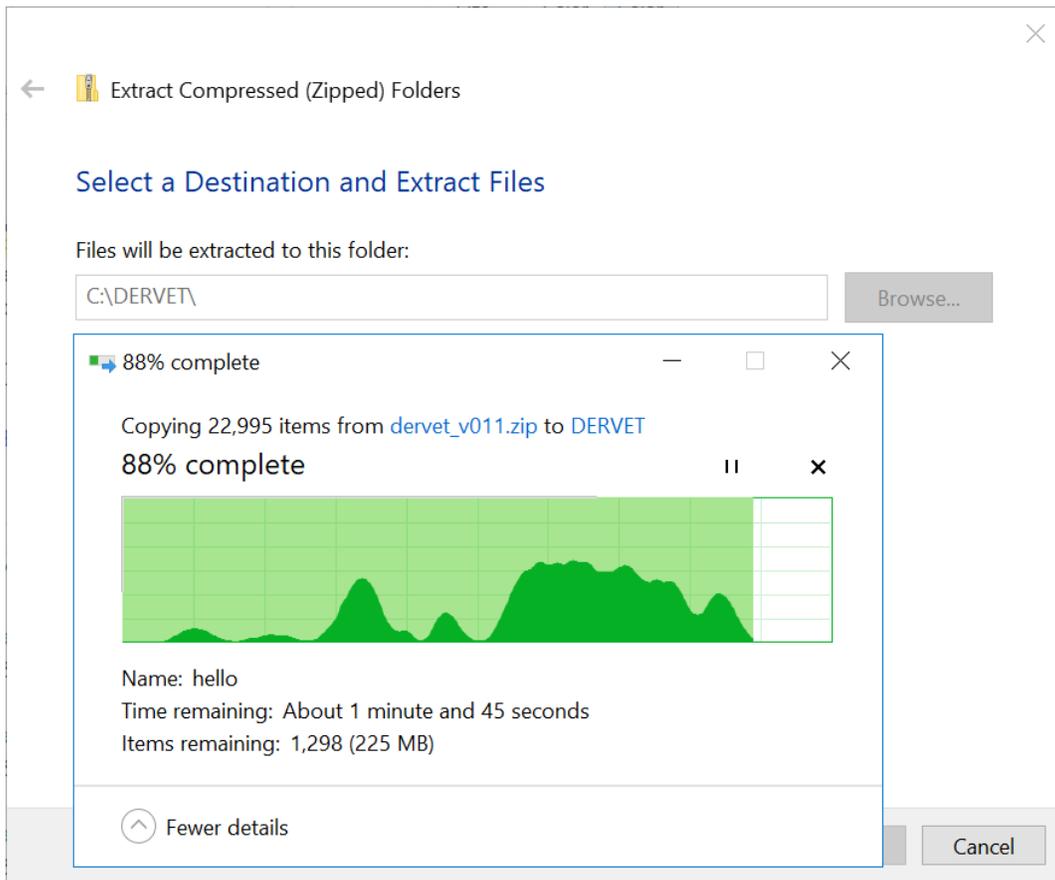
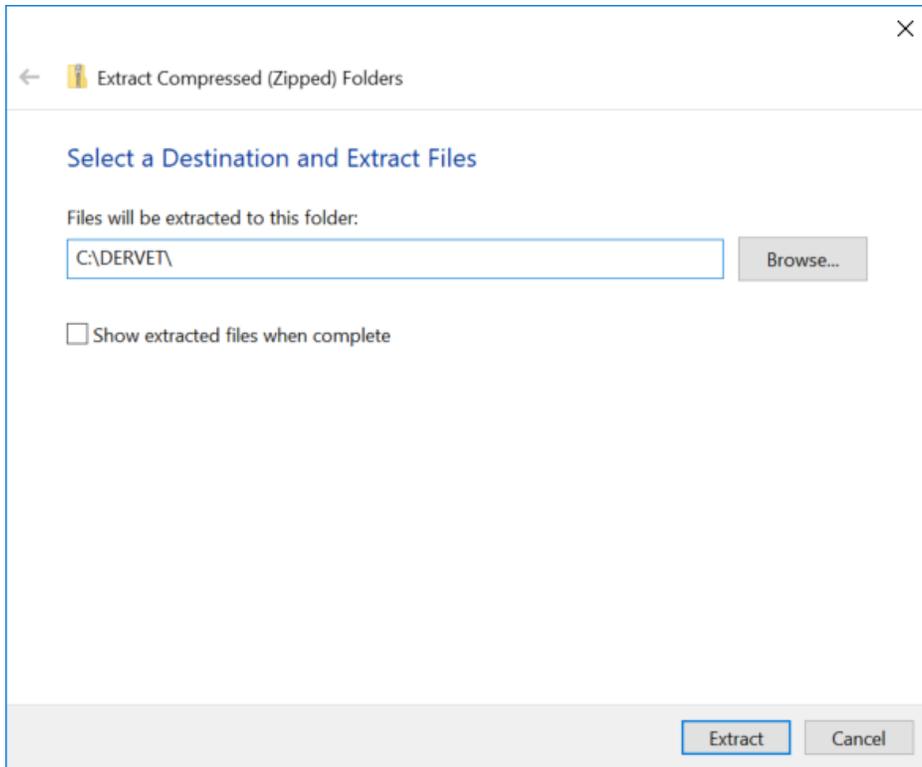
11. Download the zipped DER-VET environment.



**12. Unzip the environment precisely to the following location on your computer.**

- a. C:\DERVET\
- b. This may take a few minutes, due to the number of files in the zipped folder.





c. This may take a few minutes, due to the number of files in the zipped folder.

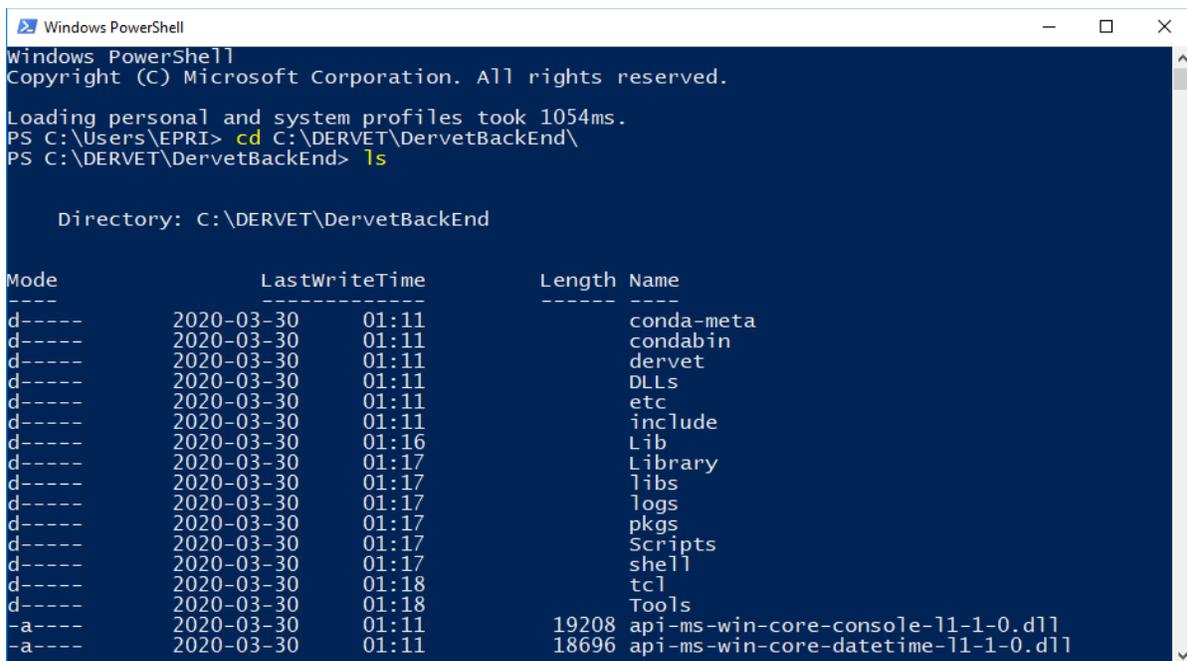
### ***Inspect the DER-VET Environment***

13. Open a terminal window.

a. Windows Powershell is recommended for the following steps.

14. Navigate into the unzipped Python environment. This is the working directory for DER-VET.

a. `> cd C:\DERVET\DervetBackEnd\`



```
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

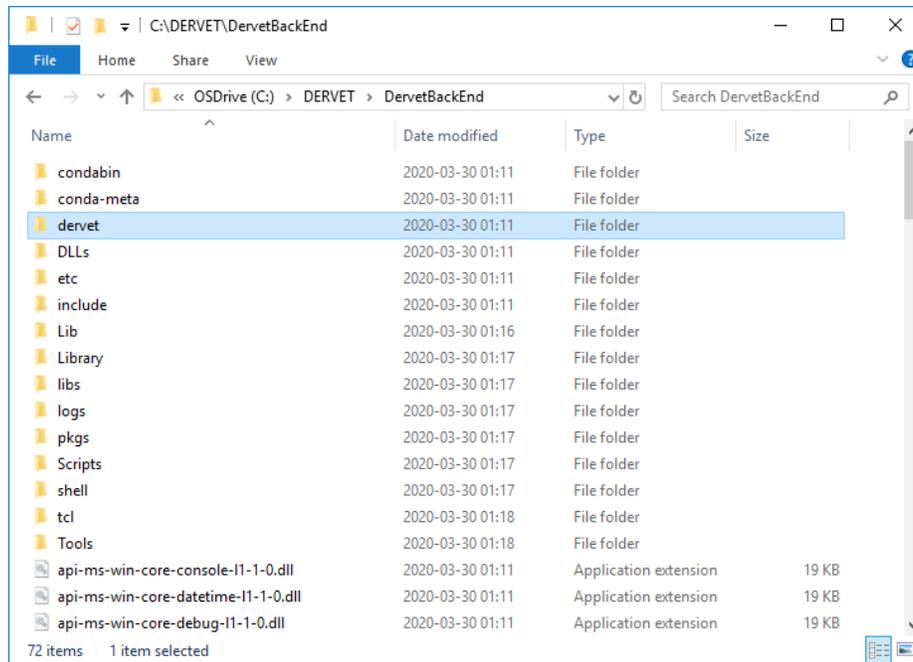
Loading personal and system profiles took 1054ms.
PS C:\Users\EPRI> cd C:\DERVET\DervetBackEnd\
PS C:\DERVET\DervetBackEnd> ls

Directory: C:\DERVET\DervetBackEnd

Mode                LastWriteTime         Length Name
----                -
d-----          2020-03-30 01:11          conda-meta
d-----          2020-03-30 01:11          condabin
d-----          2020-03-30 01:11          dervet
d-----          2020-03-30 01:11          DLLs
d-----          2020-03-30 01:11          etc
d-----          2020-03-30 01:11          include
d-----          2020-03-30 01:16          Lib
d-----          2020-03-30 01:17          Library
d-----          2020-03-30 01:17          libs
d-----          2020-03-30 01:17          logs
d-----          2020-03-30 01:17          pkgs
d-----          2020-03-30 01:17          Scripts
d-----          2020-03-30 01:17          shell
d-----          2020-03-30 01:18          tcl
d-----          2020-03-30 01:18          Tools
-a-----          2020-03-30 01:11        19208 api-ms-win-core-console-l1-1-0.dll
-a-----          2020-03-30 01:11        18696 api-ms-win-core-datetime-l1-1-0.dll
```

b. C:\DERVET\DervetBackEnd should include the following folders and files:

- i. Scripts\
- ii. dervet\
- iii. python.exe
- iv. LICENSE\_PYTHON.txt



c. Check the contents of the folder with Windows Explorer or use the `ls` command in Powershell.

i. `> ls`

### ***Install and Bind Optimization Solvers***

15. Run these 5 lines in your Powershell window:

```
C:\DERVET\DervetBackEnd\Scripts\conda.exe install --yes -c conda-forge glpk
```

```
$env:CVXOPT_BUILD_GLPK=1
```

```
$env:CVXOPT_GLPK_LIB_DIR="C:\DERVET\DervetBackEnd\Library\lib"
```

```
$env:CVXOPT_GLPK_INC_DIR="C:\DERVET\DervetBackEnd\Library\include"
```

```
C:\DERVET\DervetBackEnd\Scripts\pip.exe install cvxopt
```

If successful, move to the next section of instruction. Otherwise, continue to step 6.

16. Install the GLPK solver with the following command

```
C:\DERVET\DervetBackEnd\Scripts\conda.exe install -c conda-forge glpk
```

17. The environment will look for the listed and other relevant packages.

a. Accept the installation for the necessary packages found.

```

Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Loading personal and system profiles took 4512ms.
PS C:\DERVET\DervetBackEnd> C:\DERVET\DervetBackEnd\Scripts\conda.exe install -c conda-forge glpk
Collecting package metadata: done
Solving environment: done

## Package Plan ##

  environment location: C:\DERVET\DervetBackEnd

added / updated specs:
- glpk

The following packages will be downloaded:

package | build | size | channel
-----|-----|-----|-----
ca-certificates-2019.11.28 | hecc5488_0 | 182 KB | conda-forge
certifi-2019.11.28 | py36h9f0ad1d_1 | 149 KB | conda-forge
conda-4.8.3 | py36h9f0ad1d_1 | 3.1 MB | conda-forge
conda-package-handling-1.6.0 | py36h70ac491_2 | 702 KB | conda-forge
glpk-4.65 | h2fa13f4_1002 | 3.2 MB | conda-forge
openssl-1.1.1e | hfa6e2cd_0 | 4.7 MB | conda-forge
python_abi-3.6 | 1_cp36m | 4 KB | conda-forge
tqdm-4.44.1 | pyh9f0ad1d_0 | 48 KB | conda-forge
-----|-----|-----|-----
Total: | | 12.1 MB |

The following NEW packages will be INSTALLED:

conda-package-han~ | conda-forge/win-64::conda-package-handling-1.6.0-py36h70ac491_2
python_abi | conda-forge/win-64::python_abi-3.6-1_cp36m
tqdm | conda-forge/noarch::tqdm-4.44.1-pyh9f0ad1d_0

The following packages will be UPDATED:

ca-certificates | 2019.6.16-hecc5488_0 --> 2019.11.28-hecc5488_0
certifi | pkgs/main::certifi-2019.3.9-py36_0 --> conda-forge::certifi-2019.11.28-py36h9f0ad1d_1
conda | 4.6.14-py36_0 --> 4.8.3-py36h9f0ad1d_1
glpk | 4.65-h2fa13f4_1001 --> 4.65-h2fa13f4_1002
openssl | 1.1.1b-hfa6e2cd_2 --> 1.1.1e-hfa6e2cd_0

Proceed ([y]/n)?

```

18. When the installation is complete, create the following environment variables to prepare the binding of the GLPK library just installed with the CVXOPT library to be installed. The Windows Powershell instructions are as follows:

```

$env:CVXOPT_BUILD_GLPK=1

$env:CVXOPT_GLPK_LIB_DIR="C:\DERVET\DervetBackEnd\Library\lib"

$env:CVXOPT_GLPK_INC_DIR="C:\DERVET\DervetBackEnd\Library\include"

```

```

Select Windows PowerShell
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Loading personal and system profiles took 1159ms.
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_BUILD_GLPK=1
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_GLPK_LIB_DIR="C:\DERVET\DervetBackEnd\Library\lib"
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_GLPK_INC_DIR="C:\DERVET\DervetBackEnd\Library\include"
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_BUILD_GLPK=1
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_GLPK_LIB_DIR=C:\DERVET\DervetBackEnd\Library\lib
PS C:\DERVET\DervetBackEnd> $env:CVXOPT_GLPK_INC_DIR=C:\DERVET\DervetBackEnd\Library\include
PS C:\DERVET\DervetBackEnd> C:\DERVET\DervetBackEnd\Scripts\pip.exe install cvxopt
Collecting cvxopt
  Downloading https://files.pythonhosted.org/packages/7b/9b/462fdfe8dc5fb49a4e56044f5aa5a5aa9a164b277c5f1ebd92201e0aa261/cvxopt-1.2.4-cp36-cp36m-win_amd64.whl (815kB)
    100% |#####| 819kB 7.3MB/s
Requirement already satisfied: mkl in c:\dervet\dervetbackend\lib\site-packages (from cvxopt) (2019.0)
Requirement already satisfied: intel-openmp in c:\dervet\dervetbackend\lib\site-packages (from mkl->cvxopt) (2019.0)
Installing collected packages: cvxopt
Successfully installed cvxopt-1.2.4
PS C:\DERVET\DervetBackEnd>

```

19. Install CVXOPT with GLPK bindings now set.

```
C:\DERVET\DervetBackEnd\Scripts\pip.exe install cvxopt
```

### **Confirm Proper Completion of Installation**

Run the default case in DER-VET. to confirm proper installation of the environment. The default case is a solar plus storage deployment performing customer-side of the meter retail energy time shift and demand charge reduction.

20. Locate the DER-VET folder named `dervet` in your working directory.

21. Navigate into the `dervet` folder.

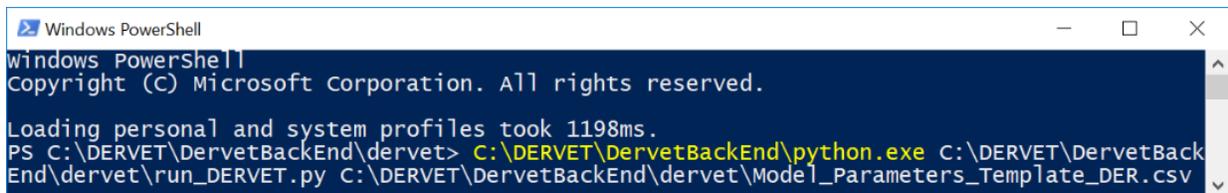
22. This should contain folders and files such as:

- a. `Data\`
- b. `Results\`
- c. `run_DERVET.py`
- d. `Model_Parameters_Template_DER.csv`

23. In Powershell command line, enter the following to run the default DER-VET case:

- a. Copy the full file path to the version of python that is included in DER-VET and paste it into your open command prompt followed by a space.
- b. Enter the full path to your `run_DERVET.py` script without the quotation marks into your command prompt, followed by a space .
- c. Enter the full path to your `Model_Parameters_Template_DER.csv` file into your open command prompt and then press enter.
- d. The full command should look like:

```
> C:\DERVET\DervetBackEnd\python.exe  
C:\DERVET\DervetBackEnd\dervet\run_DERVET.py  
C:\DERVET\DervetBackEnd\dervet\Model_Parameters_Template_DER.csv
```



```
Windows PowerShell  
Copyright (C) Microsoft Corporation. All rights reserved.  
Loading personal and system profiles took 1198ms.  
PS C:\DERVET\DervetBackEnd\dervet> C:\DERVET\DervetBackEnd\python.exe C:\DERVET\DervetBackEnd\dervet\run_DERVET.py C:\DERVET\DervetBackEnd\dervet\Model_Parameters_Template_DER.csv
```

24. If your installation worked, the tool should run produce results in the `.\Results` folder.

- a. You may see the following output on the command line:
  - i. `18:31:27: Running Optimization Problem for 2017-01-01 00:00:00...`

- ii. C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:781: RuntimeWarning: overflow encountered in long\_scalars
  - iii. self.max\_big\_small\_squared < big\*small\*\*2:
  - iv. C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:782: RuntimeWarning: overflow encountered in long\_scalars
  - v. self.max\_big\_small\_squared = big\*small\*\*2
  - vi. Long-step dual simplex will be used
- b. This is an indication the optimization is running and computing a result.
  - c. The following output indicate the optimization is complete:
    - i. Results have been saved to: .\Results\ ...
    - ii. Full runtime: ...

```

Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Loading personal and system profiles took 1366ms.
PS C:\DERVET\DervetBackEnd> C:\DERVET\DervetBackEnd\python.exe C:\DERVET\DervetBackEnd\dervet\run_DERVET.py
C:\DERVET\DervetBackEnd\dervet\Model_Parameters_Template_DER.csv
C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:781: RuntimeWarning: overflow encountered
in long_scalars
  if self.max_big_small_squared < big*small**2:
Long-step dual simplex will be used
C:\DERVET\DervetBackEnd\lib\site-packages\cvxpy\problems\problem.py:782: RuntimeWarning: overflow encountered
in long_scalars
  self.max_big_small_squared = big*small**2
Long-step dual simplex will be used
at hour 37
Results have been saved to: ./Results/_15_15_54_04_01_2020
DER results have been saved to: ./Results/_15_15_54_04_01_2020
PS C:\DERVET\DervetBackEnd>

```

## Running DER-VET

1. Navigate into dervet.
2. Set up your case using Model\_Parameters\_Template\_DER.csv (see Section 6 for more details)
  - a. Save your case under a new name. This can be located anywhere but must be reachable from the dervet directory.
  - b. The default case set up when dervet is downloaded is PV plus Storage performing customer-side of the meter retail energy time shift and demand charge reduction.

### 3. Run DER-VET

- a. Assume that we are running the default case described by the `Model_Parameter_Template_DER.csv`, but we saved it within the directory `Data` called `case1.csv`

```
> C:\DERVET\DervetBackEnd\python.exe  
C:\DERVET\DervetBackEnd\dervet\run_DERVET.py  
C:\DERVET\DervetBackEnd\dervet\Model_Parameters_Template_DER.csv
```

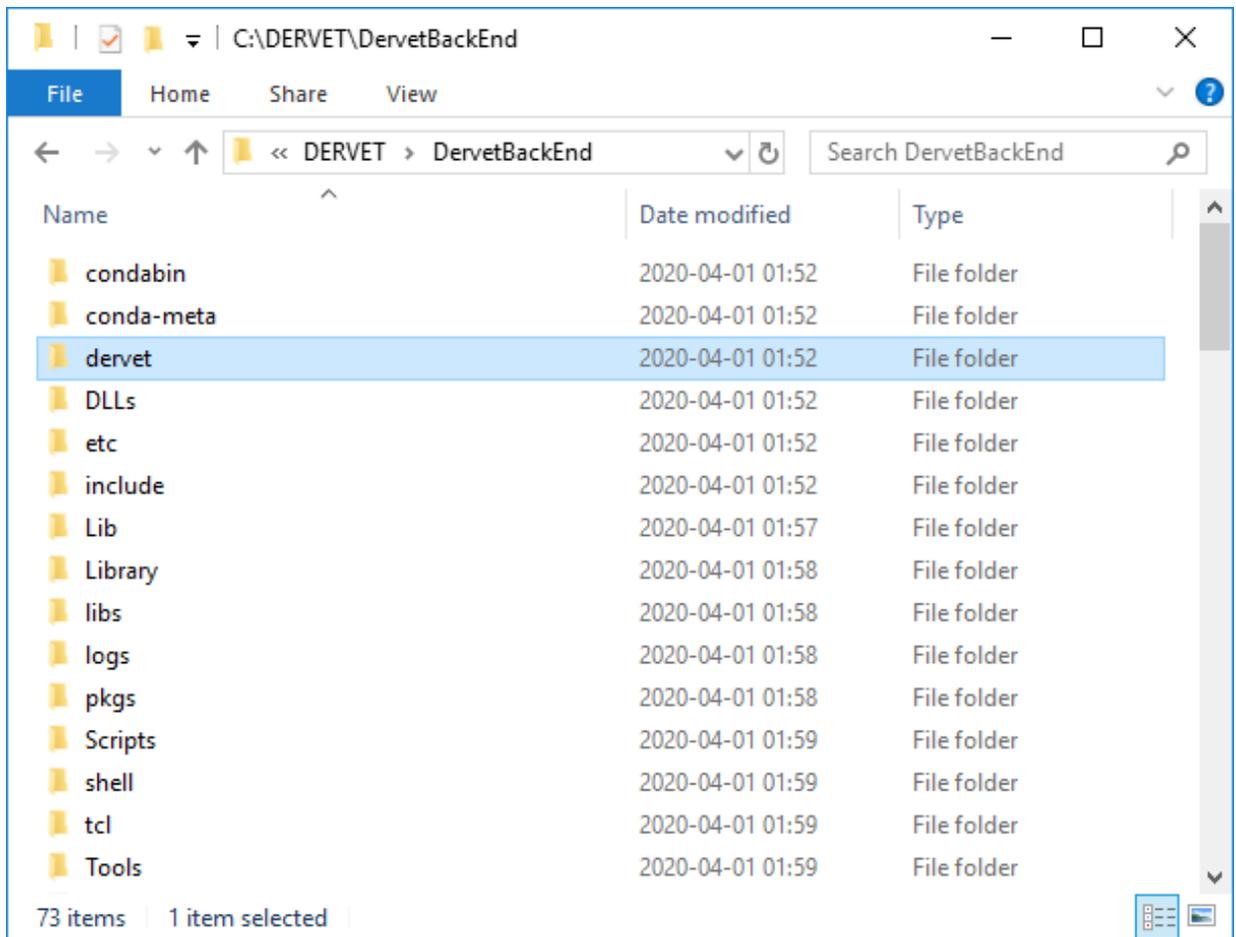
### 4. Confirm DER-VET ran to completion.

- a. Once the run has completed and results saved in the `.\Results` folder.

## Updating DER-VET

The DER-VET code is updated regularly. When new version of code is released, users can simply replace the previous version of the code with the newly released code **without needing to reinstall the environment** according the steps above.

6. Download the newly released and updated version of the DER-VET environment.
7. Unzip the standalone Python environment.
8. Locate the `dervet\` folder in the newly released environment.
9. Copy the updated code into the DER-VET environment and working directory.
  - a. Though previous DER-VET code does not need to be removed, its removal is recommended to ensure the latest, most updated code is being used.
10. Be sure to save and transfer any files from the previous `Data\` and `Results\` folders.



## DER-VET Community Edition

DER-VET Community Edition (CE) is an open-source user interface for EPRI's DER-VET software. This option enables users to run DER-VET and use the graphical user interface (GUI) from a self-hosted website. This document provides instructions on how to install, configure and use DER-VET CE.

### Prerequisites for DER-VET Community Edition

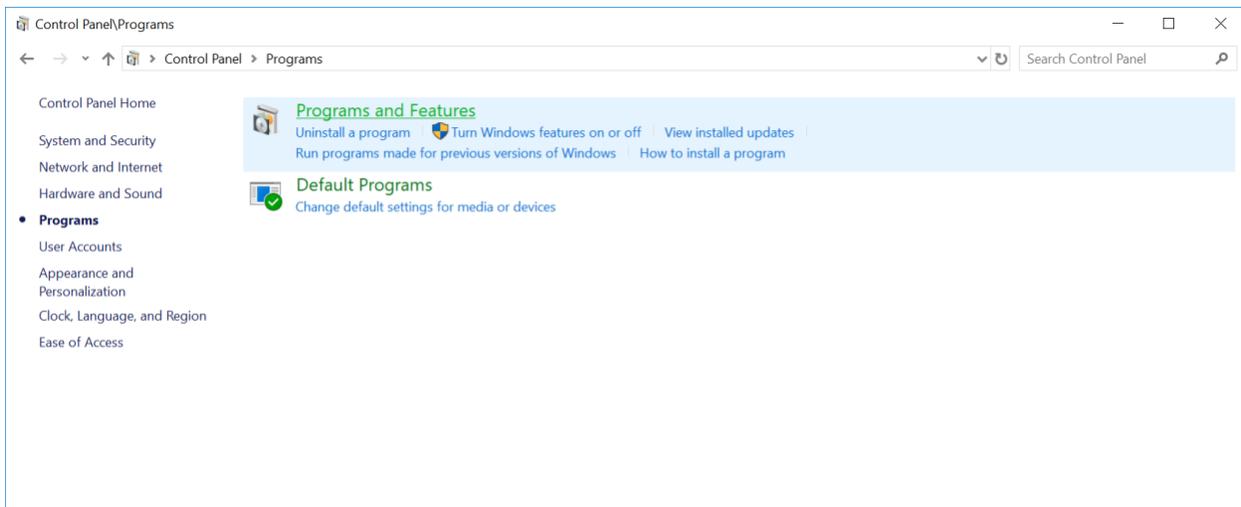
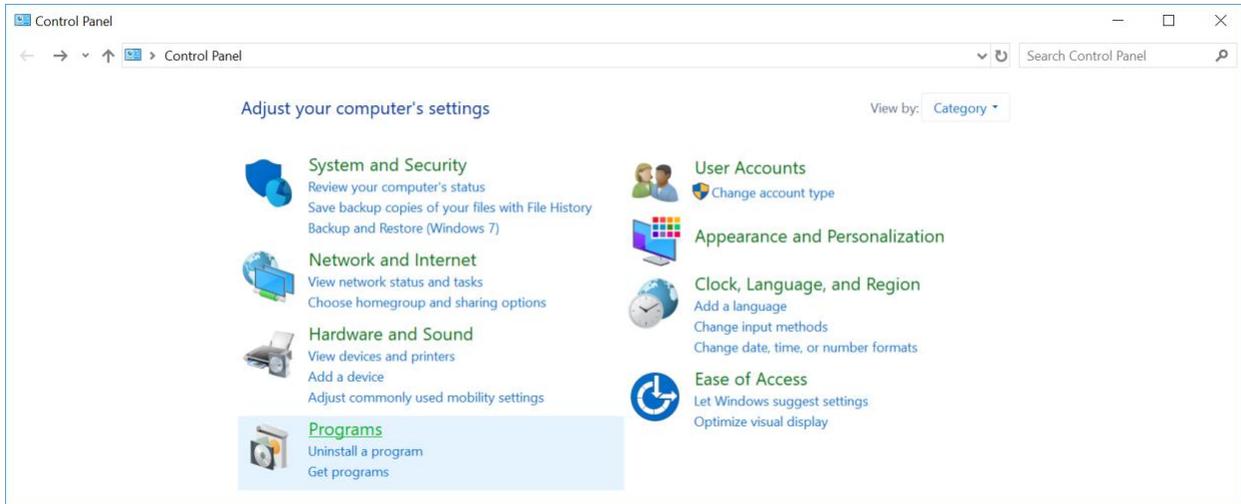
Your computer must use the Microsoft Windows operating system. DER-VET CE supports any personal version of Windows 7 or later and any server version of Windows Server 2012 or later.

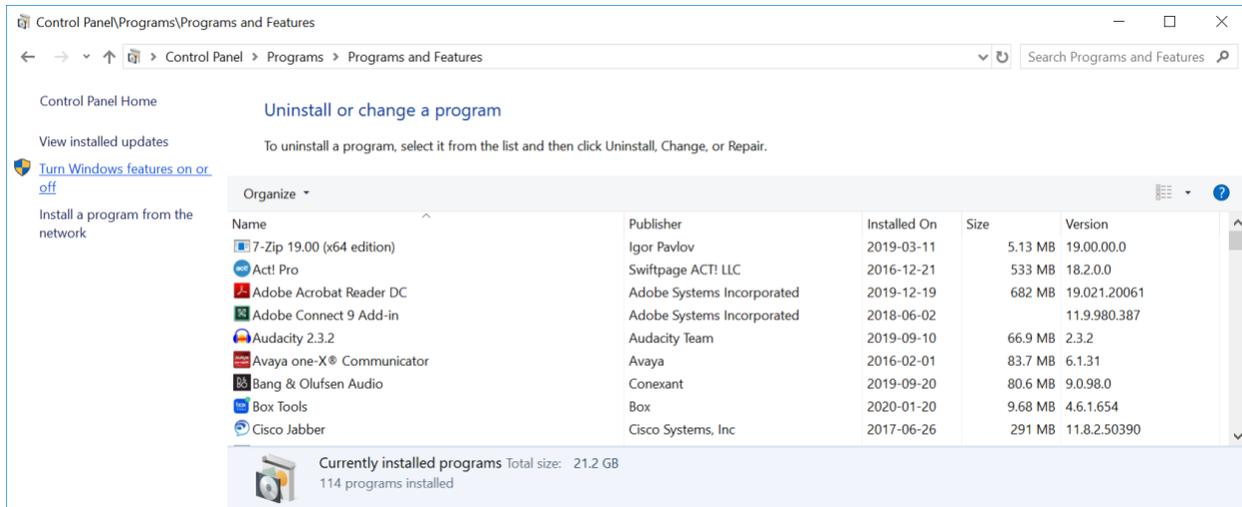
Additionally, you must have the following software installed:

- Internet Information Services (IIS) 7 or later
- Microsoft SQL Server 2012 or later
- EPRI's DER-VET software

## Installing Internet Information Services

In Windows, open the **Control Panel**, go to **Programs and Features** and click **Turn Windows features on or off**. Depending on the version of Windows you are using, you should find an option titled **Internet Information Services** or **Web Server (IIS)**.

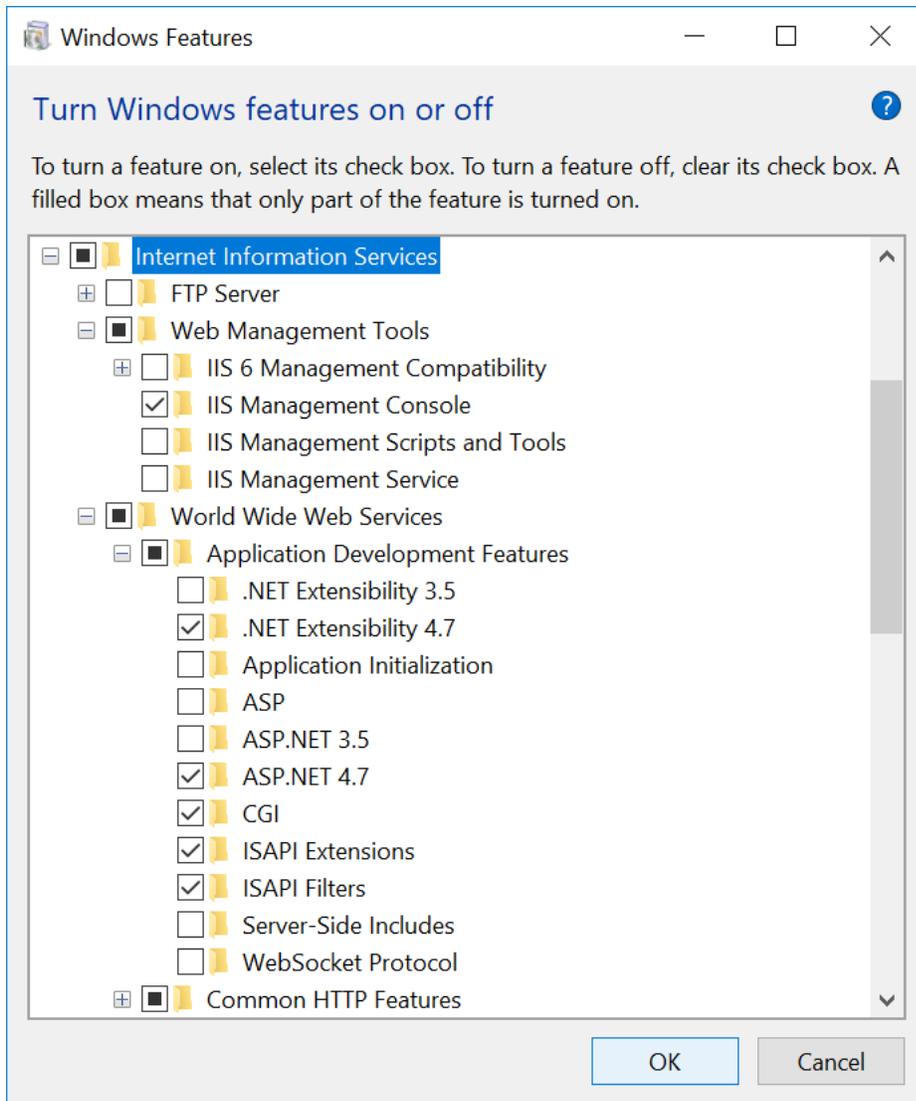




Expand this feature and make sure that the following options are enabled. The exact wording and location of these items will differ across different versions of Windows:

- **Internet Information Services or Web Server (IIS)**
  - Web Management Tools
    - IIS Management Console
  - World Wide Web Services
    - Application Development Features
      - .NET Extensibility 4.x
      - ASP.NET 4.x
      - ISAPI Extensions
      - ISAPI Filters

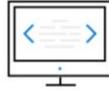
Seek to also check the Internet Information Systems -> World Wide Web Services -> Common HTTP Features -> **Static Content** checkbox to ensure web styles are served correctly to the web browser client.



### ***Installing Microsoft SQL Server***

DER-VET CE requires **Microsoft SQL Server 2012** or later. If you do not already have Microsoft SQL Server installed, you can download and install [Microsoft SQL Server Express](#), which is a free edition of SQL Server.

## Or, download a free specialized edition



### Developer

SQL Server 2019 Developer is a full-featured free edition, licensed for use as a development and test database in a non-production environment.

[Download now](#) ↓



### Express

SQL Server 2019 Express is a free edition of SQL Server, ideal for development and production for desktop, web, and small server applications.

[Download now](#) ↓

# SQL Server 2019 Express Edition

Select an installation type:

## Basic

Select Basic installation type to install the SQL Server Database Engine feature with default configuration.

## Custom

Select Custom installation type to step through the SQL Server installation wizard and choose what you want to install. This installation type is detailed and takes longer than running the Basic install.

## Download Media

Download SQL Server setup files now and install them later on a machine of your choice.

SQL Server transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#)

15.1911.4567.1

SQL Server 2019



# Express Edition

Select an installation type:

## Basic

Select Basic installation type to install the SQL Server Database Engine feature with default configuration.

## Custom

Select Custom installation type to step through the SQL Server installation wizard and choose what you want to install. This installation type is detailed and takes longer than running the Basic install.

## Download Media

Download SQL Server setup files now and install them later on a machine of your choice.

SQL Server transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#)

15.1911.4567.1

SQL Server 2019



# Express Edition

Microsoft SQL Server License Terms

## MICROSOFT SOFTWARE LICENSE TERMS

### MICROSOFT SQL SERVER 2019 EXPRESS

These license terms are an agreement between you and Microsoft Corporation (or one of its affiliates). They apply to the software named above, which includes the media on which you received it, if any. The terms also apply to any Microsoft services or software updates (except to the extent such services or updates are accompanied by new or additional terms, in which case those different terms apply prospectively and do not alter your or Microsoft's rights relating to pre-updated software or services). **IF YOU COMPLY WITH THESE LICENSE TERMS, YOU HAVE THE RIGHTS BELOW FOR EACH SERVER YOU PROPERLY LICENSE. BY USING THE SOFTWARE, YOU ACCEPT THESE TERMS. IF YOU DO NOT ACCEPT THEM, DO NOT USE THE SOFTWARE. INSTEAD, RETURN IT TO THE RETAILER FOR A REFUND OR CREDIT. If you cannot obtain a refund there, contact Microsoft or the Microsoft affiliate serving your country for information about Microsoft's refund policies. See [www.microsoft.com/worldwide](http://www.microsoft.com/worldwide). In the United States and Canada, call (800) MICROSOFT or see [www.microsoft.com/info/nareturns.htm](http://www.microsoft.com/info/nareturns.htm) <<http://www.microsoft.com/info/nareturns.htm>>.**

**IMPORTANT NOTICE: AUTOMATIC UPDATES TO PREVIOUS VERSIONS OF SQL SERVER.** If this software is installed on servers or devices running any supported editions of SQL Server prior to SQL Server 2019 (or components of any of them) this software will automatically update and replace certain files or features within those editions with files from this software. This feature cannot be switched off. Removal of these files may cause errors in

By clicking the "Accept" button, I acknowledge that I accept the License Terms and [Privacy Statement](#)

< Previous

Accept

15.1911.4567.1

SQL Server 2019 😊 — ✕

# Express Edition

Specify SQL Server install location

INSTALL LOCATION  
C:\Program Files\Microsoft SQL Server 📁 Browse

MINIMUM FREE SPACE  
**6563 MB**

DOWNLOAD SIZE  
**259 MB**

Close < Previous Install

15.1911.4567.1

SQL Server 2019 😊 — ✕

# Express Edition

Downloading install package...

Acquiring setup files... 160.004 MB / 248.988 MB 184.447 Mbps

SQL Server 2019 is also available for Linux

To obtain the SQL Server 2019 Linux images, including Containers, please see here (<https://aka.ms/sqlservercontainers>).

Pause Cancel

15.1911.4567.1

SQL Server 2019 😊 — ✕

# Express Edition

Download successful!

---

Installing...

---

Installing SQL Server... Completed Action: InitializeMsiExtension, returned True

Samples

You use the Official Microsoft GitHub Repository containing code samples for SQL Server (<https://github.com/Microsoft/sql-server-samples/tree/master/samples>) for samples on connecting to a SQL Server database, development samples for using different features like In-Memory OLTP, R-Services and much more.

You could also use Azure SQL Database Samples and Reference Implementation Repository (<https://github.com/Azure/azure-sql-database-samples>) to get different reference implementation samples for C#, java, node.js, php, python, etc. You will need to change the server name appropriately in your connection string when using these samples.

15.1911.4567.1

SQL Server 2019 😊 — ✕

# Express Edition

Installation has completed successfully!

<p><b>INSTANCE NAME</b> SQLEXPRESS</p> <p><b>SQL ADMINISTRATORS</b> [Empty]</p> <p><b>FEATURES INSTALLED</b> SQLENGINE</p> <p><b>VERSION</b> 15.0.2000.5, RTM</p>	<p><b>CONNECTION STRING</b> Server=localhost\SQLEXPRESS;Database=master;Trusted_Connection=True [📄]</p> <p><b>SQL SERVER INSTALL LOG FOLDER</b> C:\Program Files\Microsoft SQL Server\150\Setup Bootstrap\Log\2020012 [📁]</p> <p><b>INSTALLATION MEDIA FOLDER</b> C:\SQL2019\Express_ENU [📁]</p> <p><b>INSTALLATION RESOURCES FOLDER</b> C:\Program Files\Microsoft SQL Server\150\SSEI\Resources [📁]</p>
---	---

A computer restart is required to complete your installation.

15.1911.4567.1

## Installing SQL Server Management Studio

Also install [SQL Server Management Studio](#). SQL Server Management Studio (SSMS) is a tool for managing SQL Server databases.

Download SQL Server Management Studio (SSMS)

11/03/2019 • 4 minutes to read • +26

**APPLIES TO:** SQL Server, Azure SQL Database, Azure Synapse Analytics (SQL DW), Parallel Data Warehouse

SQL Server Management Studio (SSMS) is an integrated environment for managing any SQL infrastructure, from SQL Server to Azure SQL Database. SSMS provides tools to configure, monitor, and administer instances of SQL Server and databases. Use SSMS to deploy, monitor, and upgrade the data-tier components used by your applications, and build queries and scripts.

Use SSMS to query, design, and manage your databases and data warehouses, wherever they are - on your local computer, or in the cloud.

SSMS is free!

**Download SSMS**

[Download SQL Server Management Studio \(SSMS\)](#)

SSMS 18.4 is the latest general availability (GA) version of SSMS. If you have a previous GA version of SSMS 18 installed, installing SSMS 18.4 upgrades it to 18.4.

SSMS-Setup-ENU.exe

Show all



RELEASE 18.4

# Microsoft SQL Server Management Studio

Welcome. Click "Install" to begin.

Location:

C:\Program Files (x86)\Microsoft SQL Server Management Studio 18

Change

By clicking the "Install" button, I acknowledge that I accept the [License Terms](#) and [Privacy Statement](#).

SQL Server Management Studio transmits information about your installation experience, as well as other usage and performance data, to Microsoft to help improve the product. To learn more about data processing and privacy controls, and to turn off the collection of this information after installation, see the [documentation](#).

Install

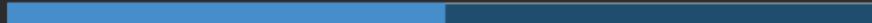
Close



RELEASE 18.4

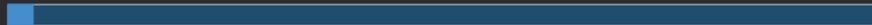
# Microsoft SQL Server Management Studio

Package Progress



Microsoft Visual C++ 2017 Redistributable (x64) - 14.16.27029

Overall Progress



Cancel



RELEASE 18.4

## Microsoft SQL Server Management Studio

Restart required in order to complete setup.

All specified components have been installed successfully.

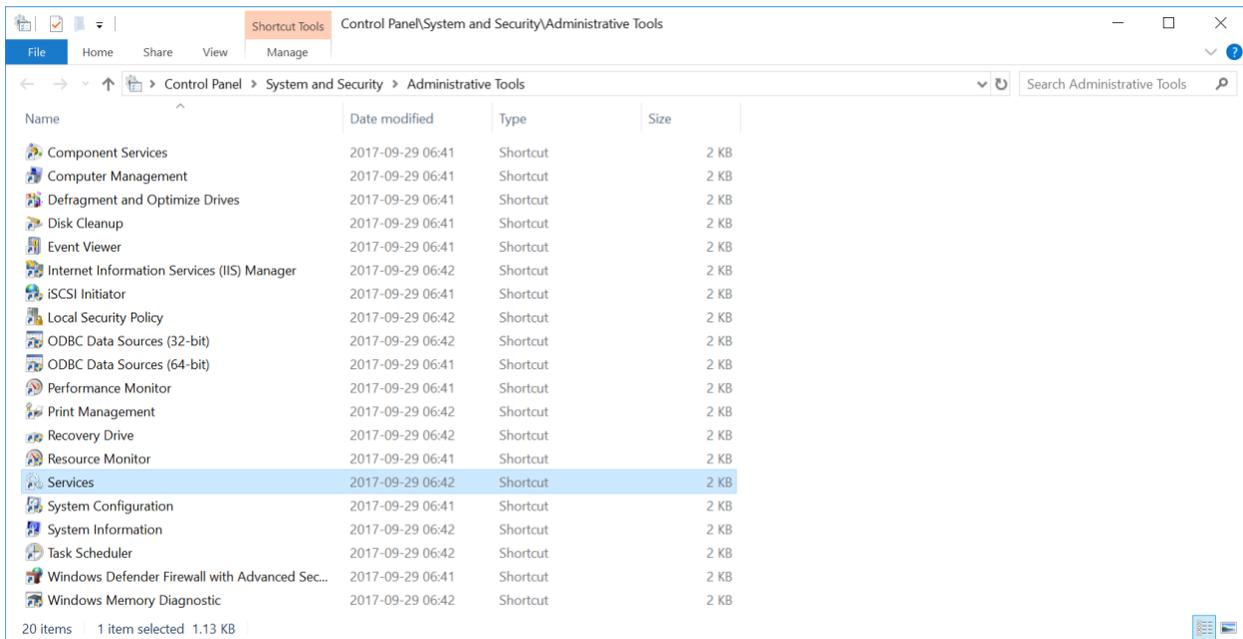
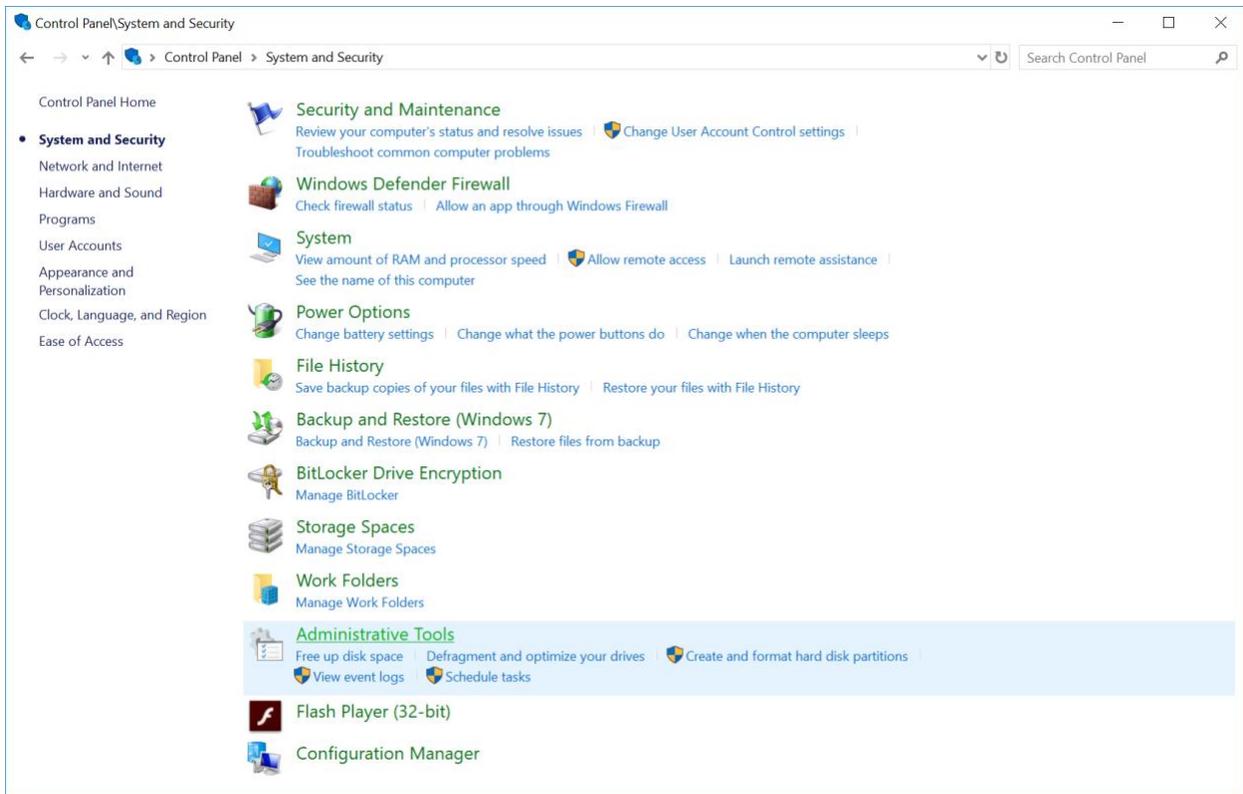
The computer needs to be restarted before setup can continue.

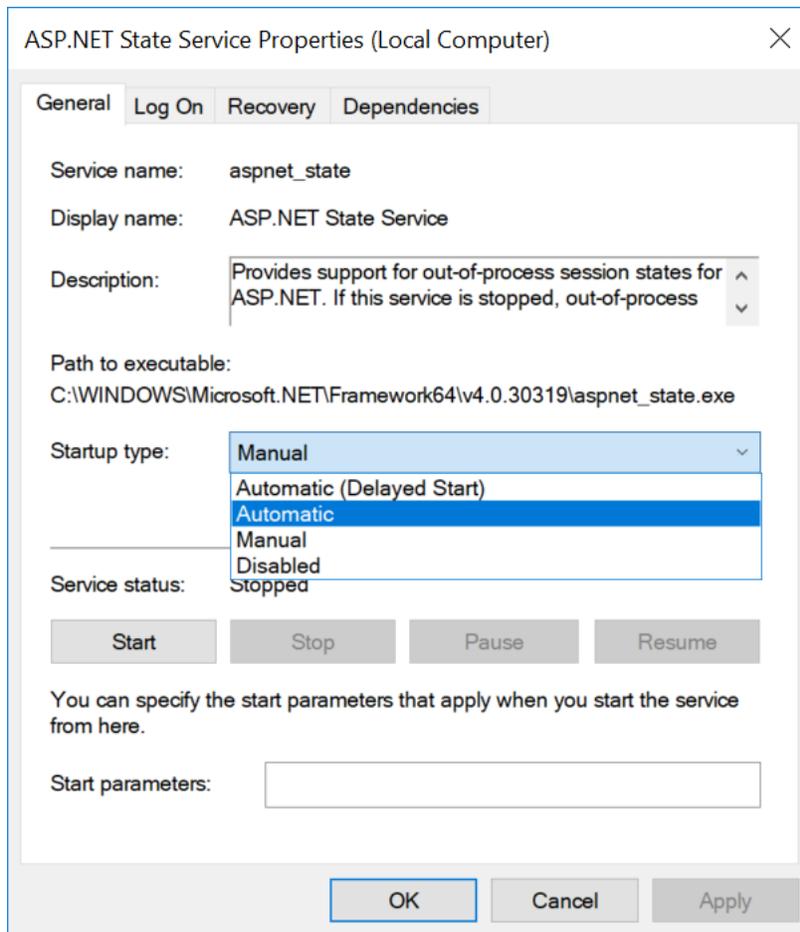
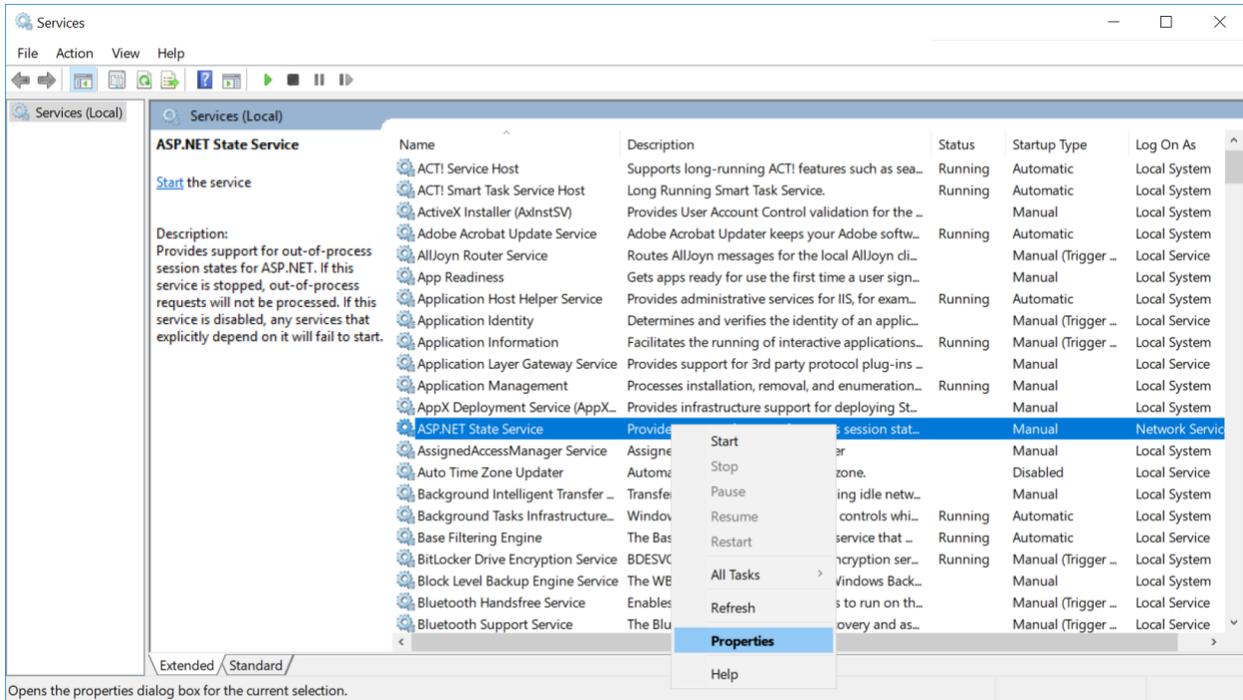
Restart

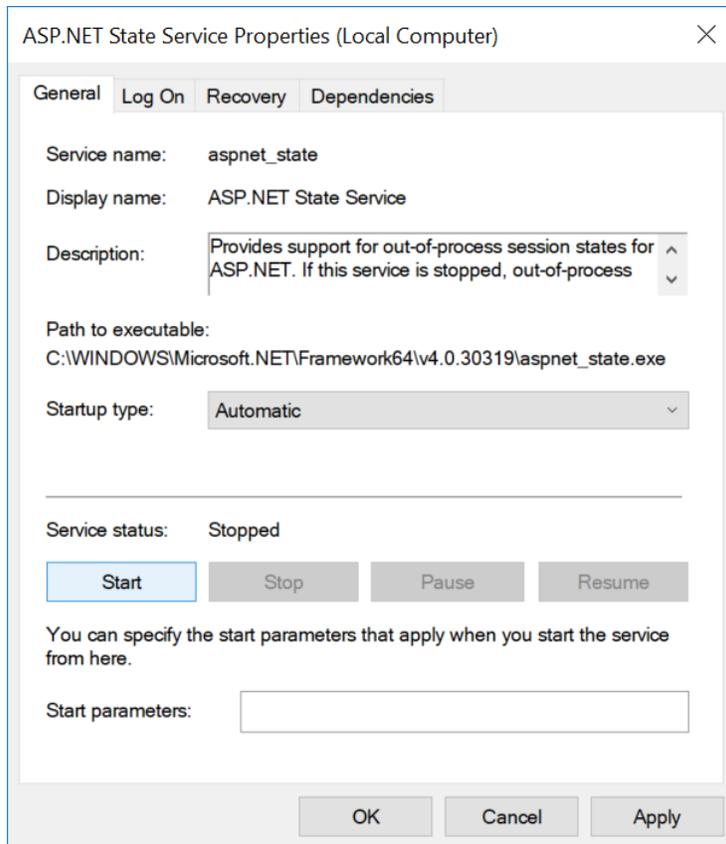
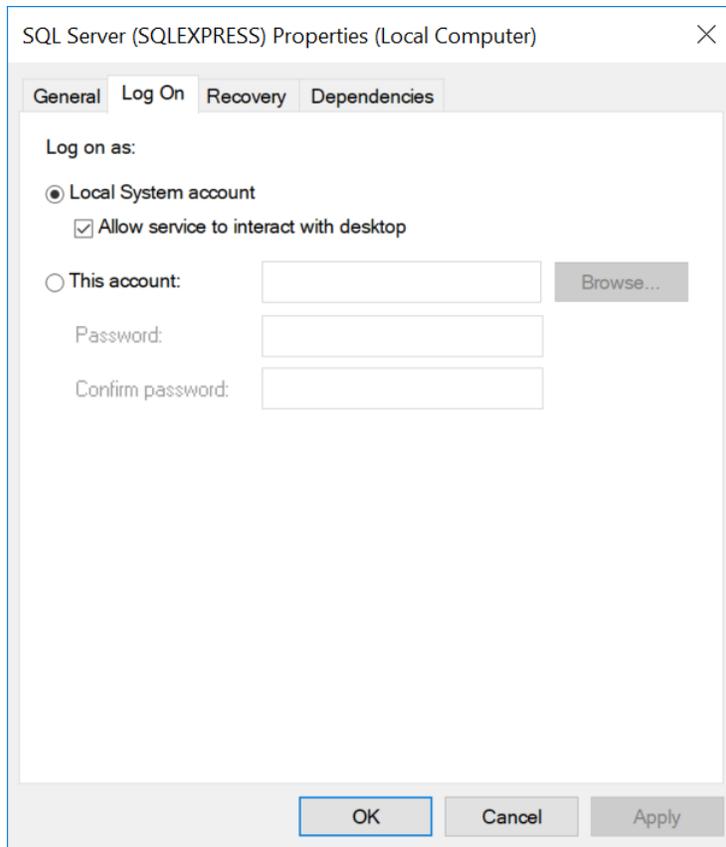
Close

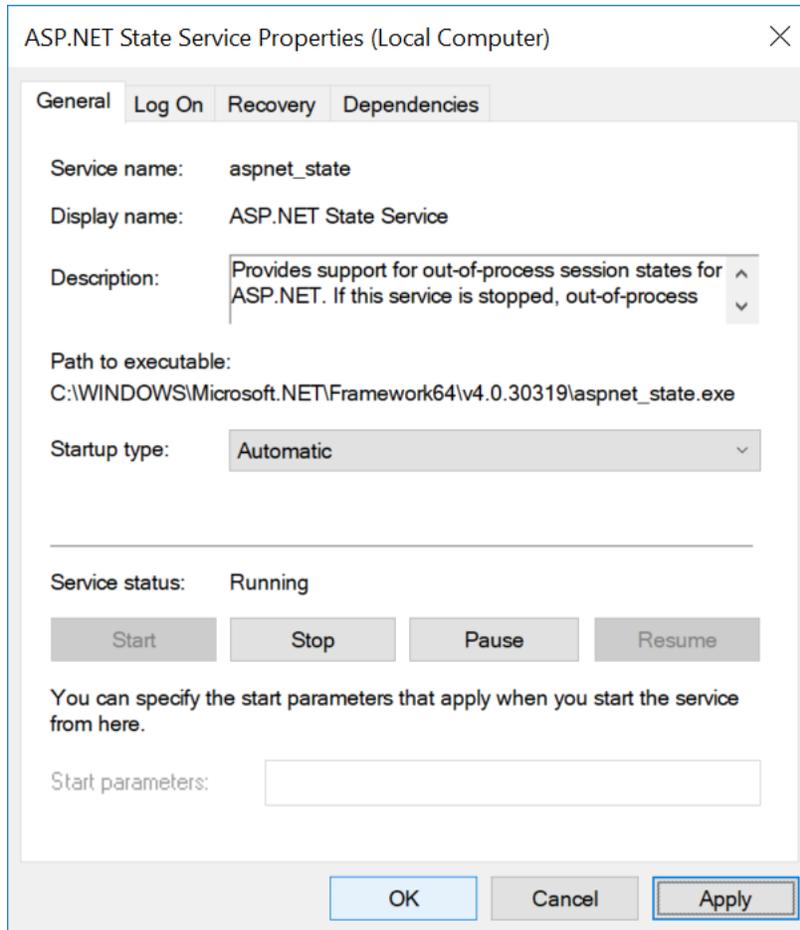
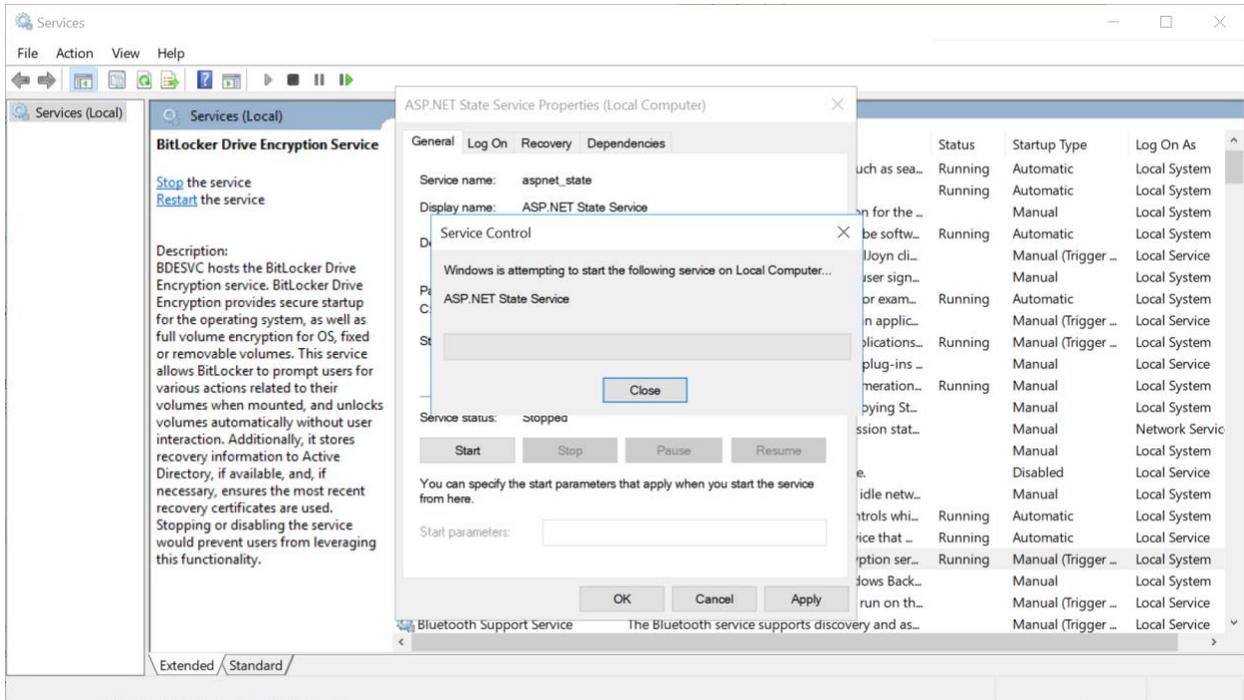
### ***Configuring the ASP.NET State Server Service***

After installing Internet Information Services, you need to ensure that the ASP.NET State Server service is running and is configured to automatically run on system startup. Go to **Control Panel** and drill into the **Administrative Tools** section. Next, open the **Services** tool.









In the list of services, you should see one named **ASP.NET State Server**. Right-click this service and select **Properties**. Make sure the **Startup** type is set to **Automatic** and that the service is currently running. If its status is Stopped, click the **Start** button to start the service.

It is also recommended to click on **Logon** tab and select **Log on as: Local System account** and **Allow service to interact with desktop**. These options will simplify and stabilize the startup of the SQL Server (SQLEXPRESS) as well as allow for login via SQL Server Management Studio (SSMS).

## Installing DER-VET Community Edition

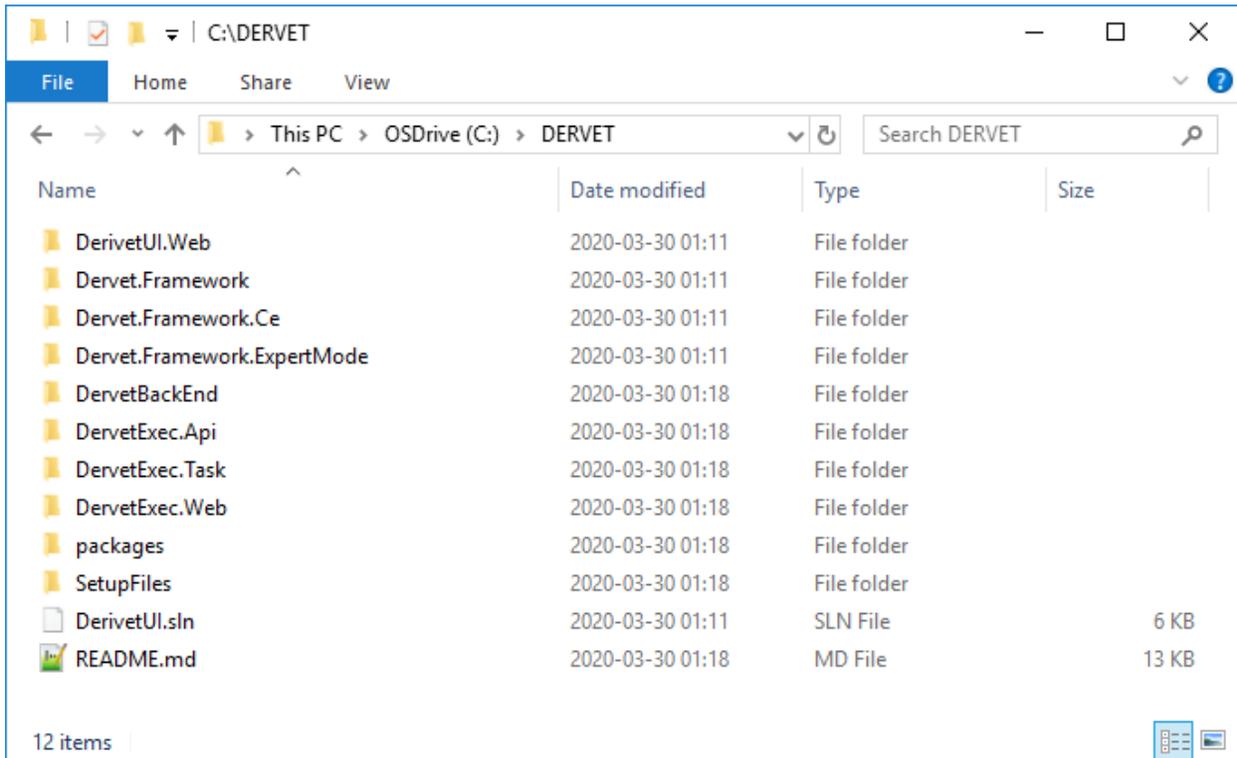
The DER-VET CE download contains three folders:

- **SetupFiles** – contains database scripts for creating the necessary database objects in Microsoft SQL Server.
- **DerivetUI.Web** – a website that serves as the user interface. This is the website that you will use to specify the inputs that get passed to EPRI's DER-VET software, and will graph the results that get generated.
- **DervetExec.Web** – a website that takes the inputs entered through the user interface website (**DerivetUI.Web**), executes EPRI's DER-VET software, and then returns the results to the user interface for reporting.

Create a folder on your hard drive and copy these three folders there. In order to provide example configuration syntax, this documentation will proceed as if the contents of the download were placed in a folder named `C:\DERVET`, meaning that there would be the following directory structure:

- `C:\DERVET`
  - `C:\DERVET\DerivetUI.Web`
  - `C:\DERVET\Dervet.Framework`
  - `C:\DERVET\Dervet.Framework.Ce`
  - `C:\DERVET\Dervet.Framework.ExpertMode`
  - `C:\DERVET\DervetBackEnd`
  - `C:\DERVET\DervetExec.Api`
  - `C:\DERVET\DervetExec.Task`
  - `C:\DERVET\DervetExec.Web`
  - `C:\DERVET\packages`
  - `C:\DERVET\SetupFiles`
  - `C:\DERVET\DerivetUI.sln`

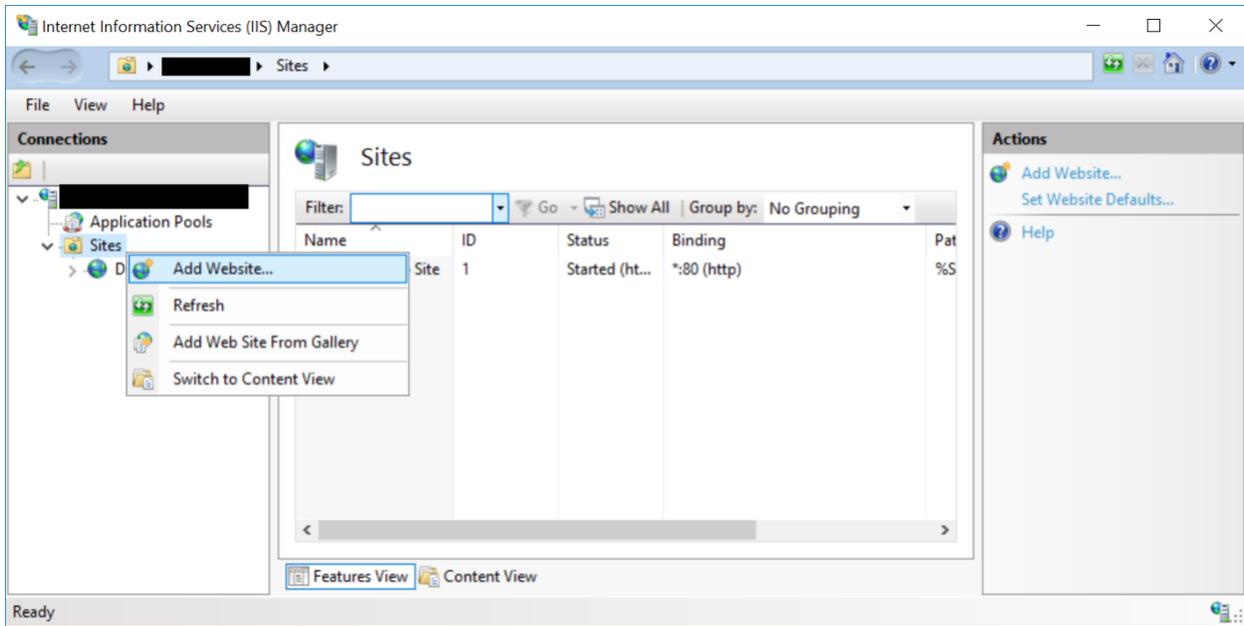
- README.md



### ***Creating the Websites in IIS***

The first step is to create websites in Internet Information Services (IIS) for both **DerivetUI.Web** and **DervetExec.Web**. Launch Internet Information Services and perform the following steps:

5. Click on the server name to reveal the Sites folder.
6. Right-click on the Sites folder and choose Add Website
7. Enter **DervetExec.Web** as the Site name and set the Physical path to the folder where the **DervetExec.Web** site resides (e.g., **C:\DERVET\DervetExec.Web**). Update the port number, if needed (e.g., **8088**).
8. Click the OK button



The screenshot shows the 'Add Website' dialog box with the following configuration:

- Site name:** DerivetExec.Web
- Application pool:** DerivetExec.Web
- Content Directory:**
  - Physical path:** C:\DERVET\DerivetExec.Web
  - Pass-through authentication:** Connect as... Test Settings...
- Binding:**
  - Type:** http
  - IP address:** All Unassigned
  - Port:** 8088
  - Host name:** (empty)
  - Example: www.contoso.com or marketing.contoso.com
- Start Website immediately

Repeat these steps to create a website for **DerivetUI.Web**:

5. Click on the server name to reveal the Sites folder.
6. Right-click on the Sites folder and choose Add Website
7. Enter **DerivetUI.Web** as the Site name and set the Physical path to the folder where the **DerivetUI.Web** site resides (e.g., C:\DERVET\DerivetUI.Web). Update the port number, if needed (e.g., 8089).
8. Click the OK button

Add Website

Site name: DerivetUI.Web Application pool: DerivetUI.Web Select...

Content Directory

Physical path: C:\DERVET\DerivetUI.Web ...

Pass-through authentication

Connect as... Test Settings...

Binding

Type: http IP address: All Unassigned Port: 8089

Host name:

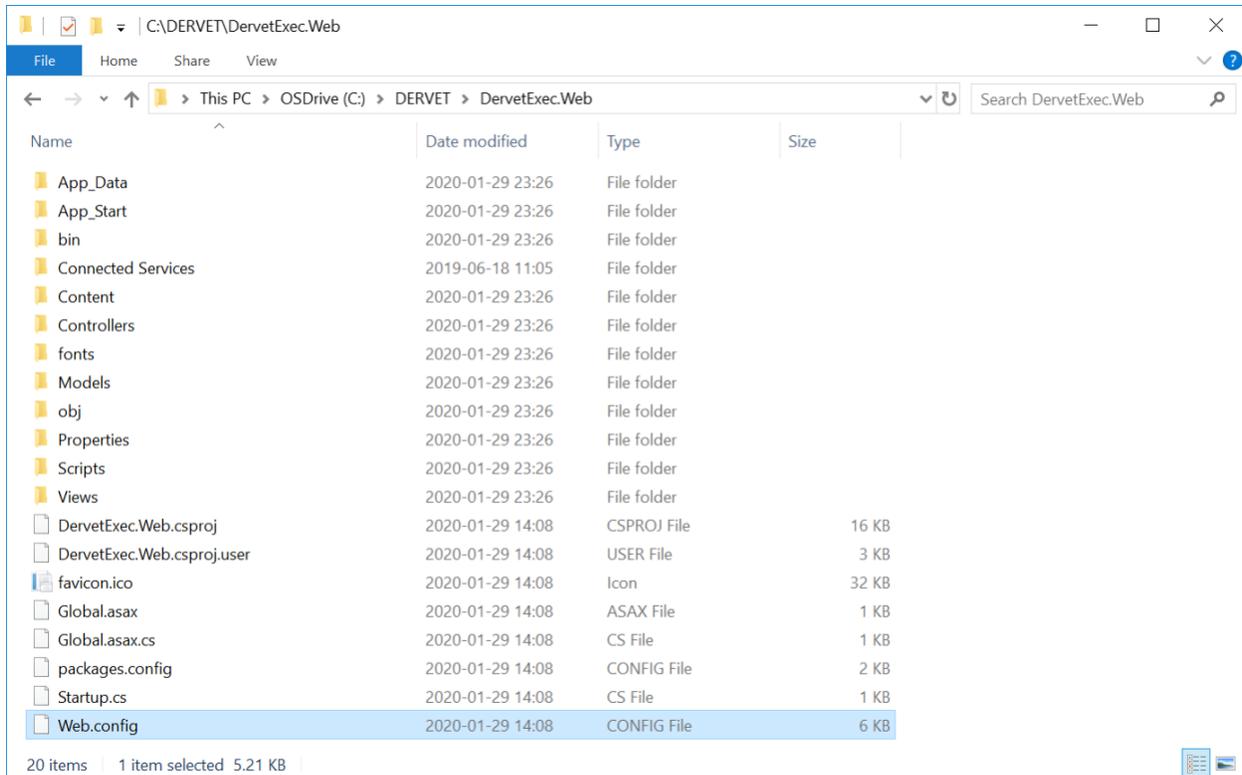
Example: www.contoso.com or marketing.contoso.com

Start Website immediately

OK Cancel

### ***Updating the Websites Configurations***

The configuration information for the `DerivetExec.Web` website is specified in the `Web.config` file in the website's root (e.g., `C:\DERVET\DerivetExec.Web\Web.config`).



Open this file with a text editor and make the following changes:

- Under the `<appSettings>` element there is a setting called `alertEmailAddress` - enter your email address here.
- Under the `<appSettings>` element there is a setting called `ResponseServerUrl` - enter the address of the `DerivetUI.Web` website here. For example, if you setup the `DerivetUI.Web` website to use port `8089` you'd use the value `http://localhost:8089/` here.

```

1 <?xml version="1.0" encoding="utf-8"?>
2 <configuration>
3   <configSections>
4     <section name="entityFramework" type="System.Data.Entity.Internal.ConfigFile.EntityFrameworkSection, EntityFramework, Version=6.0.0.0,
5       Culture=neutral, PublicKeyToken=b77a5c561934e089" requirePermission="false" />
6   </configSections>
7   <appSettings>
8     <add key="webpages:Version" value="3.0.0.0" />
9     <add key="webpages:Enabled" value="false" />
10    <add key="ClientValidationEnabled" value="true" />
11    <add key="UnobtrusiveJavaScriptEnabled" value="true" />
12    <add key="alertEmailAddress" value="youremail@example.com" />
13    <add key="ResponseServerUrl" value="http://localhost:8089/" />
14  </appSettings>
15  <connectionStrings>
16    <add name="DervetExecDBConnectionString" connectionString="data source=(local)\SQLEXPRESS;initial catalog=DervetExecDB;integrated
17      security=True;multipleactiveresultsets=True;App=EntityFramework" providerName="System.Data.SqlClient" />
18  </connectionStrings>
19  <system.web>
20    <compilation debug="true" targetFramework="4.5" />
21    <httpRuntime targetFramework="4.5" maxRequestLength="1048576" />
22    <authentication mode="Forms">
23      <forms loginUrl="~/Account/SignIn" timeout="2880">
24        <credentials passwordFormat="Clear">
25          <user name="admin" password="energy"/>
26        </credentials>
27      </forms>
28    </authentication>
29  </system.web>
30  <runtime>
31    <assemblyBinding xmlns="urn:schemas-microsoft-com:asm.v1">
32      <dependentAssembly>
33        <assemblyIdentity name="Antlr3.Runtime" publicKeyToken="eb42632606e9261f" />
34        <bindingRedirect oldVersion="0.0.0.0-3.5.0.2" newVersion="3.5.0.2" />
35      </dependentAssembly>
36    </runtime>
37 </configuration>

```

eXtensible Markup Language file      length: 5,333    lines: 99      Ln: 12    Col: 1    Sel: 135 | 3      Windows (CR LF)    UTF-8-BOM    INS

- Under the <connectionStrings> section review the connectionString setting and update it if needed. The precise connection string will depend on how you installed and configured SQL Server. If you used the default installation options you shouldn't need to modify this setting.
- The <system.web>\<authentication>\<forms>\<credentials>\<user> element specifies the username and password used to access the online DervetExec.Web status page. The status page shows information about tasks that have been sent to EPRI's DER-VET software, and the results of those tasks. Consider changing the username and/or password here to something only you know.

```

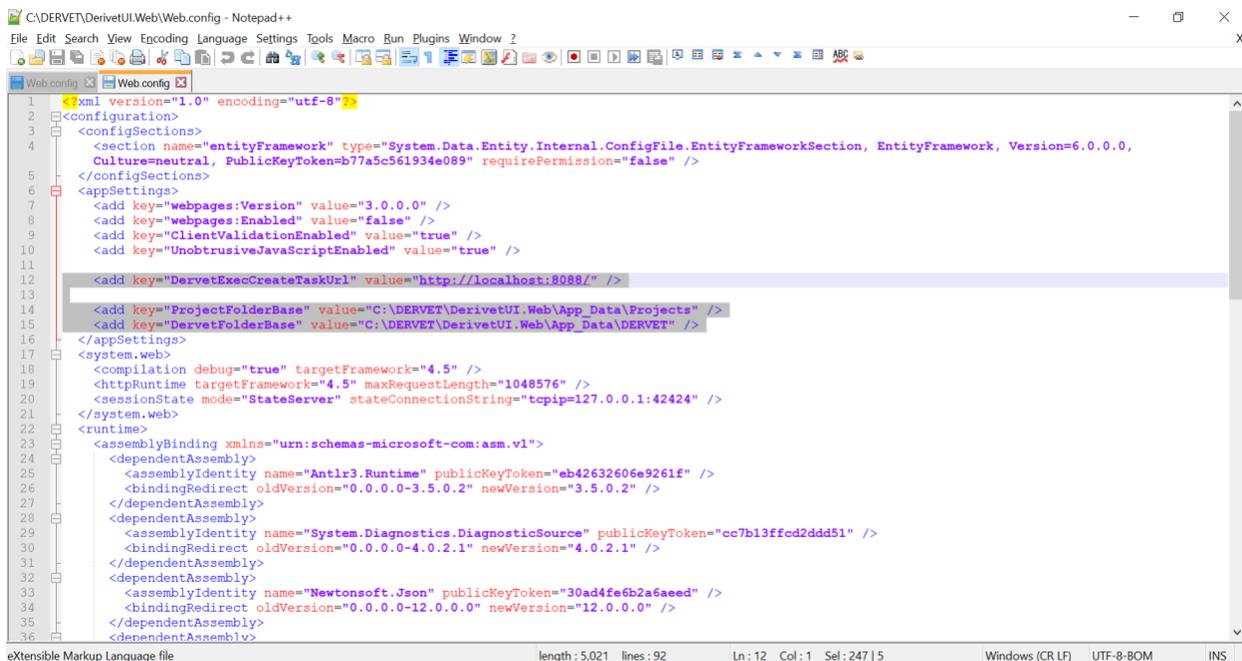
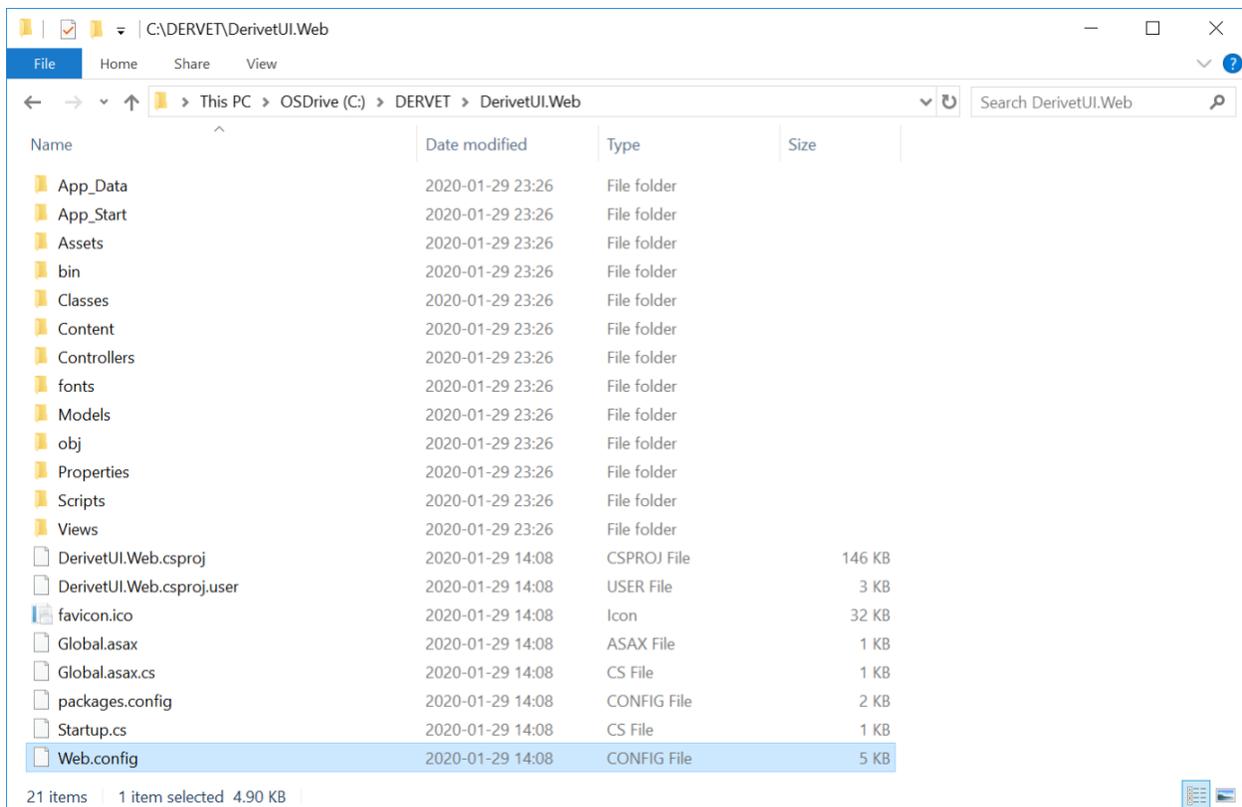
1 <?xml version="1.0" encoding="utf-8"?>
2 <configuration>
3   <configSections>
4     <section name="entityFramework" type="System.Data.Entity.Internal.ConfigFile.EntityFrameworkSection, EntityFramework, Version=6.0.0.0,
5       Culture=neutral, PublicKeyToken=b77a5c561934e089" requirePermission="false" />
6   </configSections>
7   <appSettings>
8     <add key="webpages:Version" value="3.0.0.0" />
9     <add key="webpages:Enabled" value="false" />
10    <add key="ClientValidationEnabled" value="true" />
11    <add key="UnobtrusiveJavaScriptEnabled" value="true" />
12
13    <add key="alertEmailAddress" value="youremail@example.com" />
14    <add key="ResponseServerUrl" value="http://localhost:8089/" />
15  </appSettings>
16  <connectionStrings>
17    <add name="DervetExecDBConnectionString" connectionString="data source=(local)\SQLEXPRESS;initial catalog=DervetExecDB;integrated
18      security=True;multipleactiveresultsets=True;App=EntityFramework" providerName="System.Data.SqlClient" />
19  </connectionStrings>
20  <system.web>
21    <compilation debug="true" targetFramework="4.5" />
22    <httpRuntime targetFramework="4.5" maxRequestLength="1048576" />
23    <authentication mode="Forms">
24      <forms loginUrl="~/Account/SignIn" timeout="2880">
25        <credentials passwordFormat="Clear">
26          <user name="admin" password="energy"/>
27        </credentials>
28      </forms>
29    </authentication>
30  </system.web>
31  <runtime>
32    <assemblyBinding xmlns="urn:schemas-microsoft-com:asm.v1">
33      <dependentAssembly>
34        <assemblyIdentity name="Antlr3.Runtime" publicKeyToken="eb42632606e9261f" />
35        <bindingRedirect oldVersion="0.0.0.0-3.5.0.2" newVersion="3.5.0.2" />
36      </dependentAssembly>
37    </assemblyBinding>
38  </runtime>
39 </configuration>

```

- Under the `<system.net>` section enter details for your SMTP server. This is optional. If setup, though, you will receive email notifications if an error occurs on the DerivetUI.Web website.

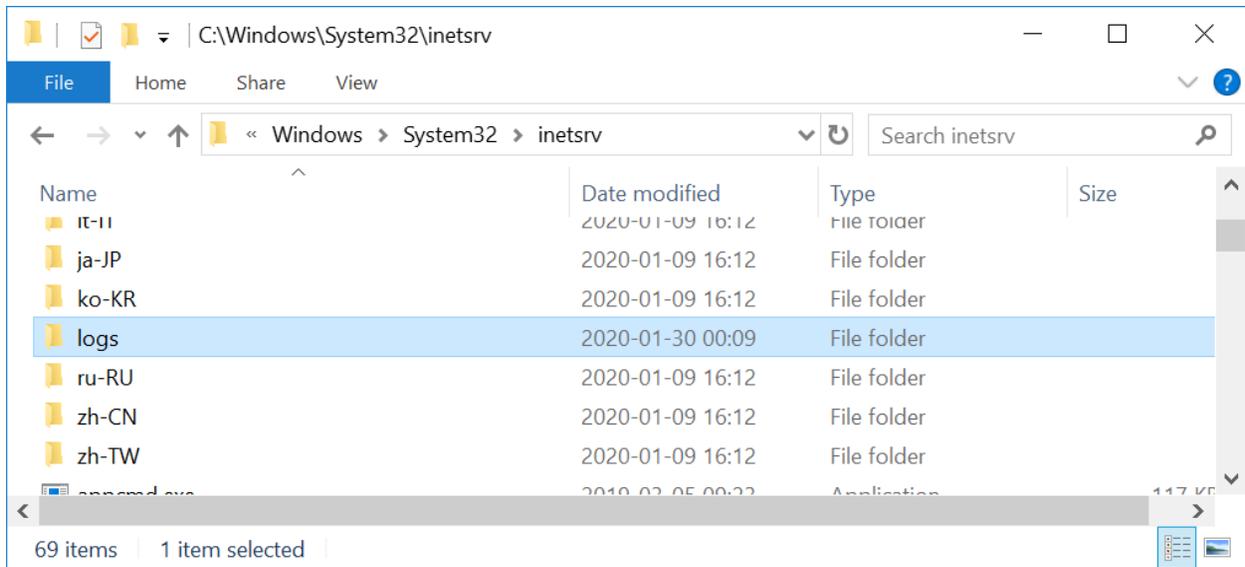
The configuration information for the DerivetUI.Web website is specified in the Web.config file in the website's root (e.g., C:\DERVET\DerivetUI.Web\Web.config). Open this file with a text editor and make the following changes:

- Under the `<appSettings>` element there is a setting called `DervetExecCreateTaskUrl` - enter the address of the DervetExec.Web website here. For example, if you setup the DervetExec.Web website to use port 8088 you'd use the value `http://localhost:8088/` here.
- Under the `<appSettings>` element there is a setting called `ProjectFolderBase` - enter the full path to the `~/App_Data/Projects` folder. For example, if you installed the DervetExec.Web website in the C:\DERVET\DerivetUI.Web folder then you'd use `C:\DERVET\DerivetUI.Web\AppData\Projects` here.
- Under the `<appSettings>` element there is a setting called `DervetFolderBase` - enter the full path to the `~/App_Data/DERVET` folder. For example, if you installed the DervetExec.Web website in the C:\DERVET\DerivetUI.Web folder then you'd use `C:\DERVET\DerivetUI.Web\AppData\DERVET` here.



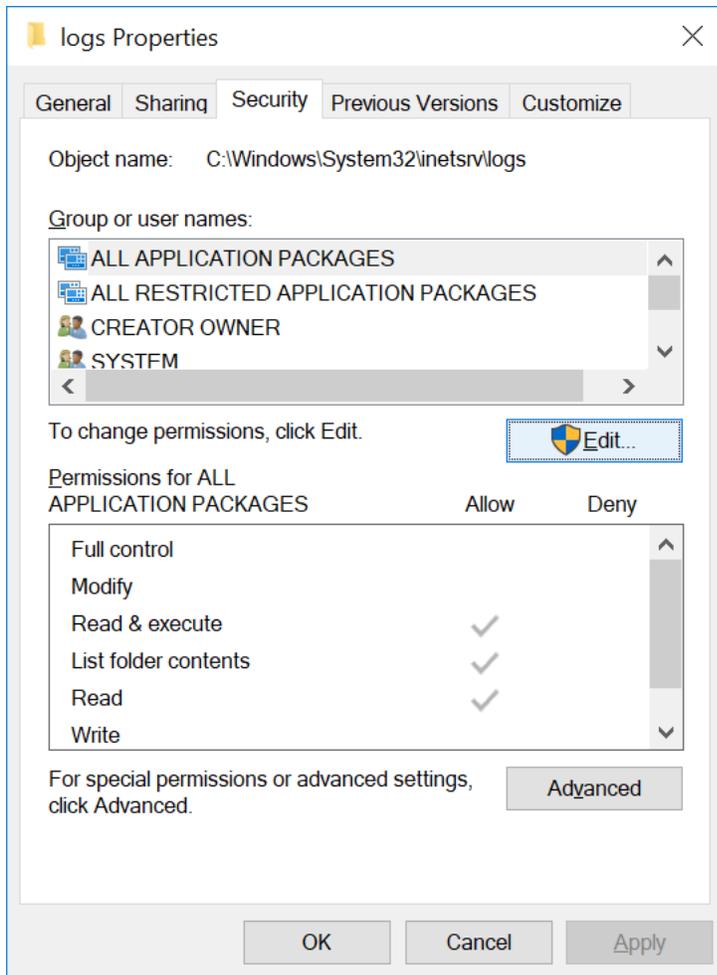
## Create Log Folder

Next, create a folder named logs in the Windows folder Windows\System32\inet\_srv (e.g., C:\Windows\System32\inet\_srv\logs). This is the folder where EPRI's DER-VET software will place log files intended for experienced developers to troubleshoot any issues with the software.

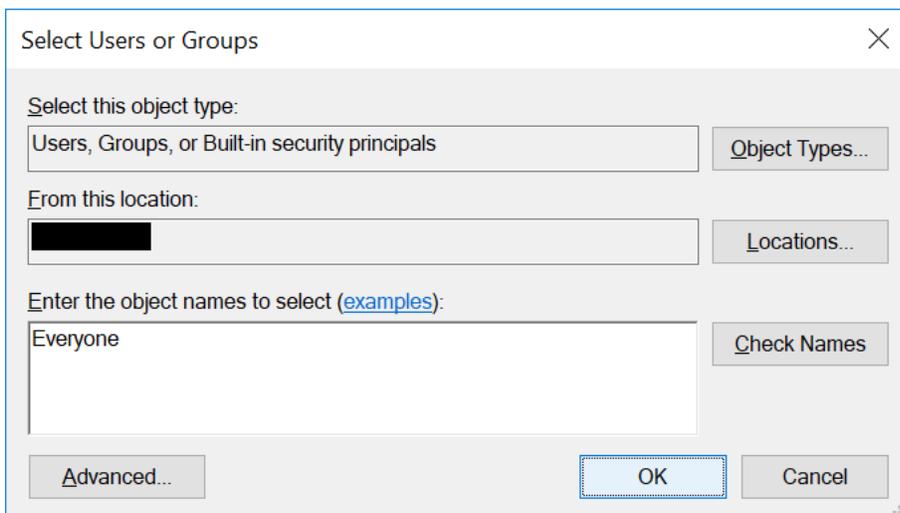
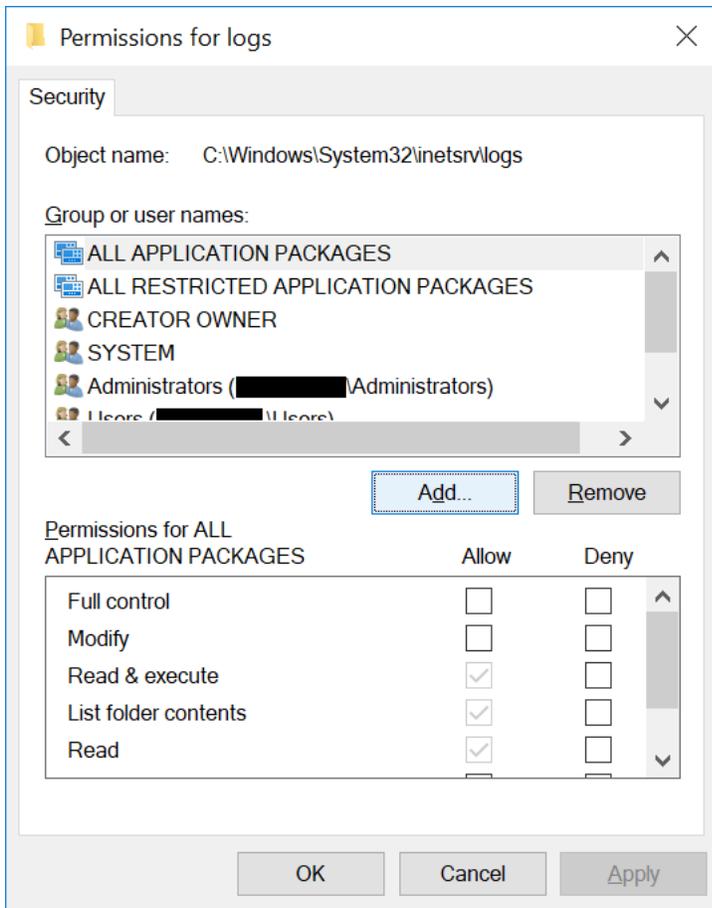


Configure the permissions to allow anyone full control to this folder. To do so, follow these steps:

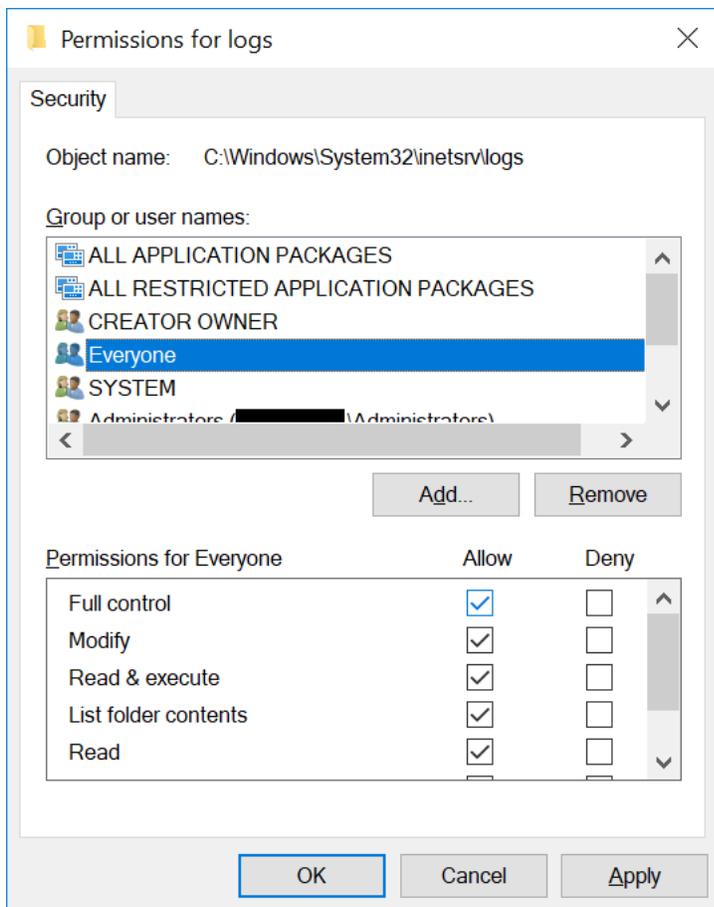
7. Right-click on the `logs` folder and choose **Properties**.
8. Go to the **Security** tab and click **Edit**.



9. Click Add and then type in Everyone and click OK.



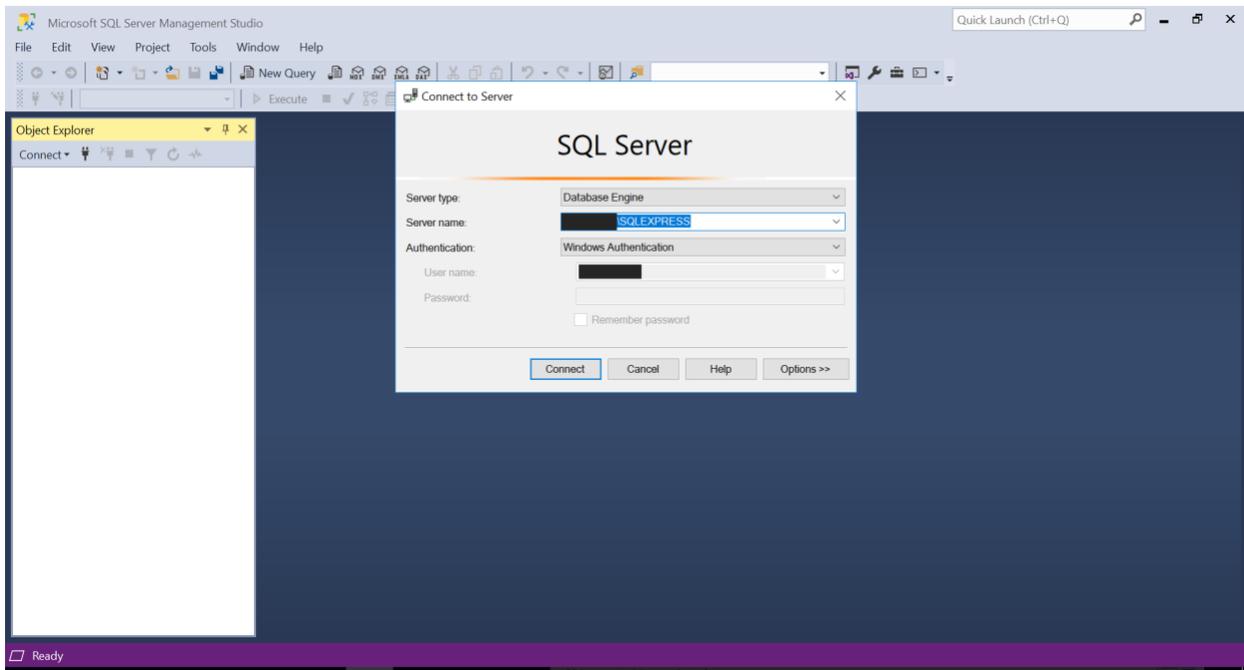
10. Check the Full control checkbox and click OK.



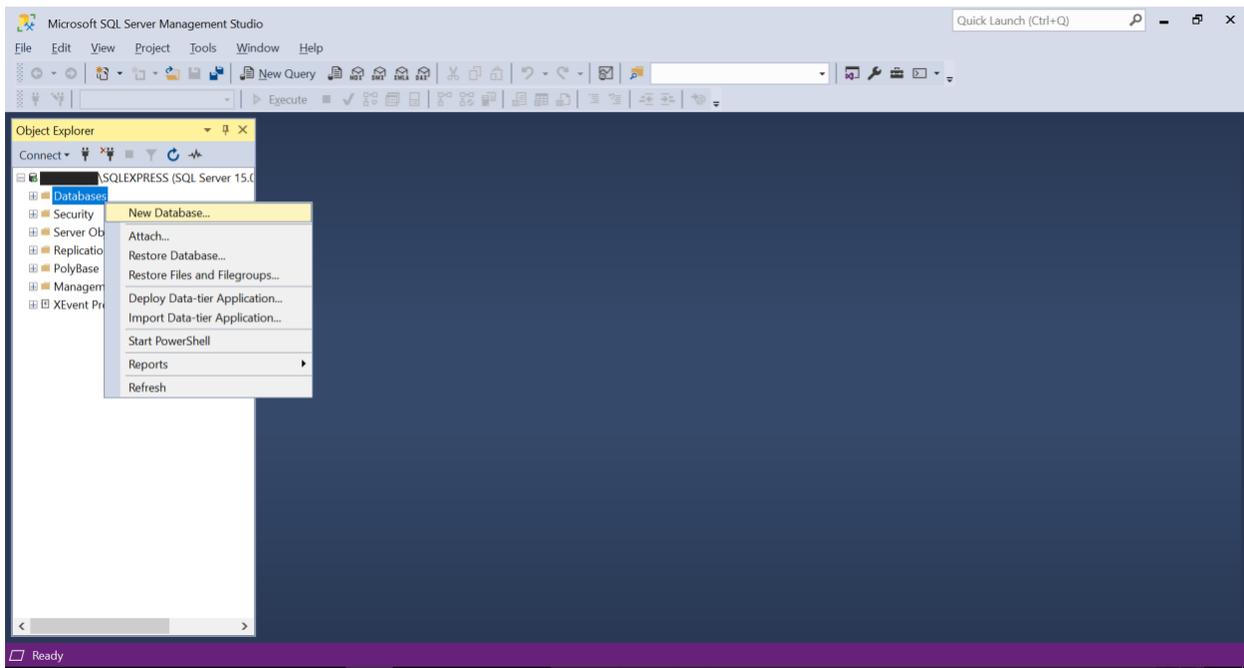
Note: If you do not create the logs folder or if you do not grant the appropriate permissions then DER-VET CE will fail whenever it attempts to run EPRI's DER-VET software and you will not be able to perform any analyses from DER-VET CE.

### Configuring Database for DER-VET Community Edition

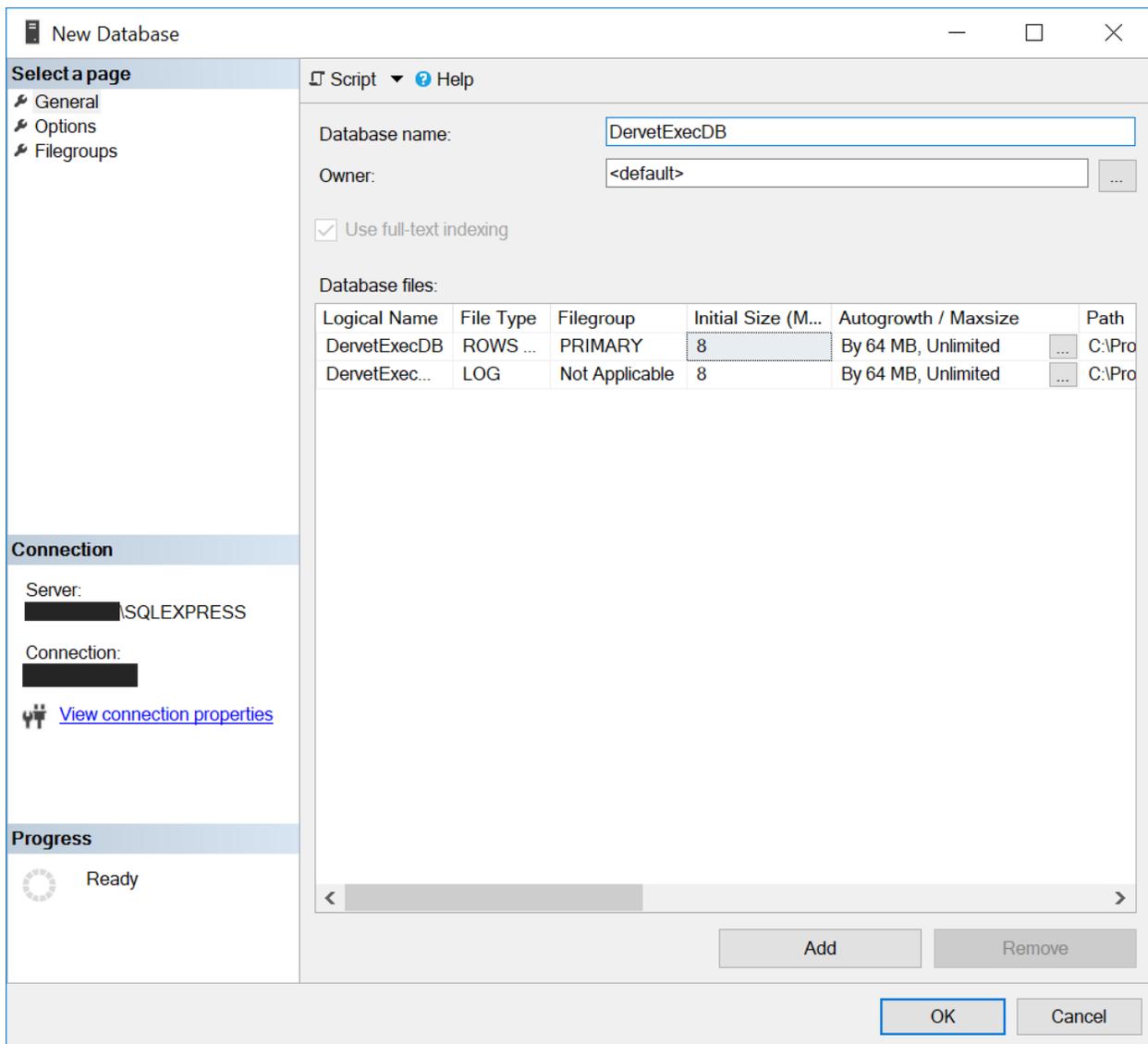
Launch **SQL Server Management Studio (SSMS)** and **Connect** to the local server designated as **SQLEXPRESS**.



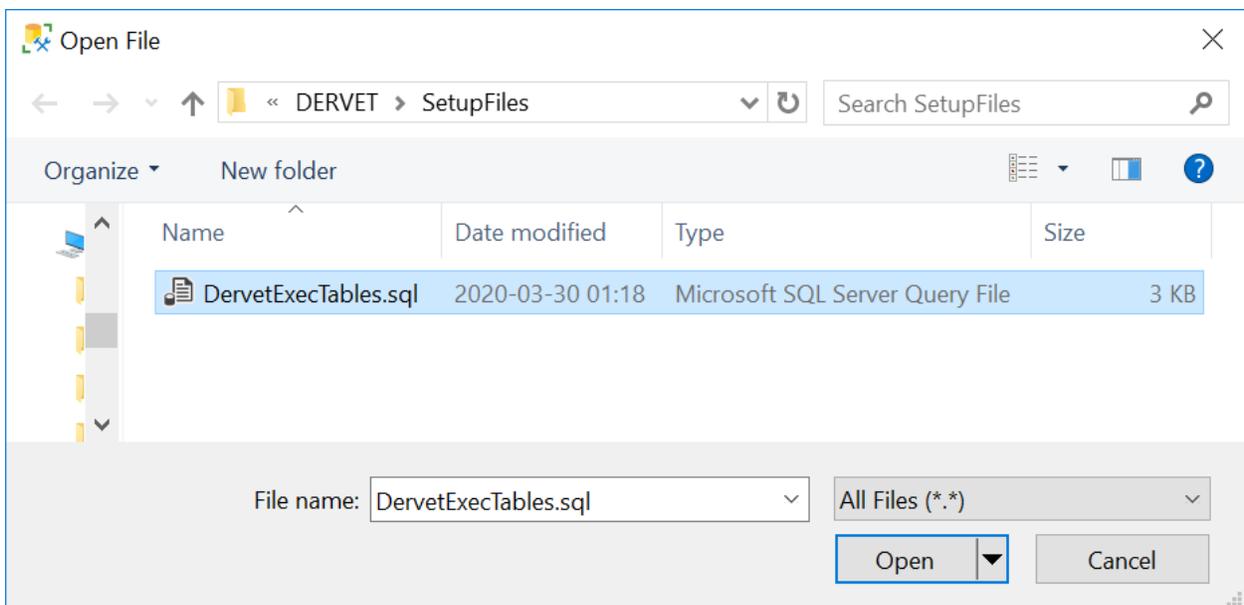
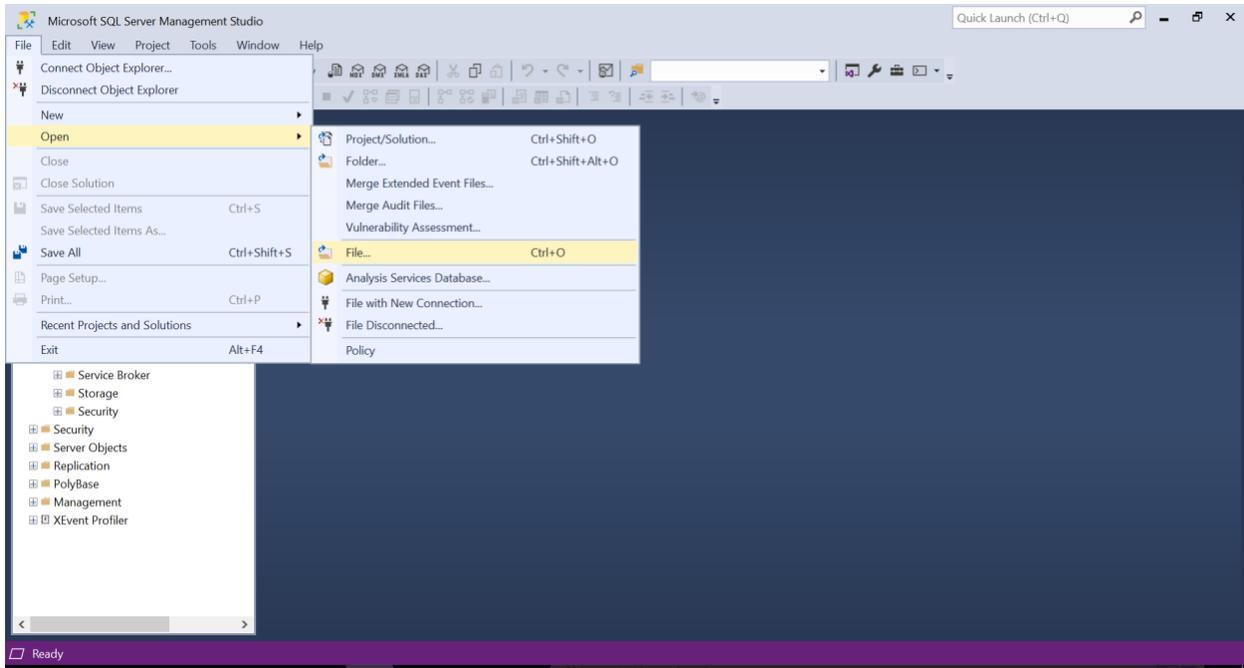
Right-click on the Databases tab and choose New Database.



Enter the Database name DervetExecDB.



Next, open the C:\DERVET\SetupFiles\DervetExecTables.sql file in SSMS.



There are three INSERT statements (lines 24-26) that add records to the dex\_Settings table. These INSERT statements need to be customized based on the folder locations in your environment.

```
INSERT INTO dex_Settings (SettingName, SettingValue) VALUES
('DerivetExecFolderBase', 'C:\DERVET\DervetBackEnd\dervet')
```

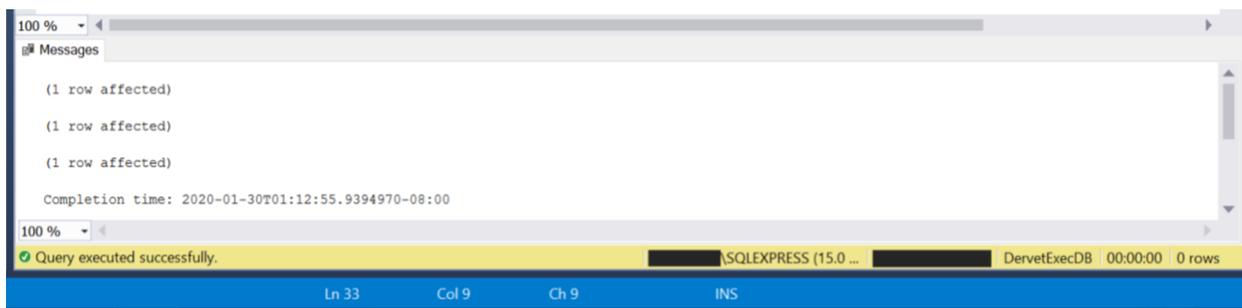
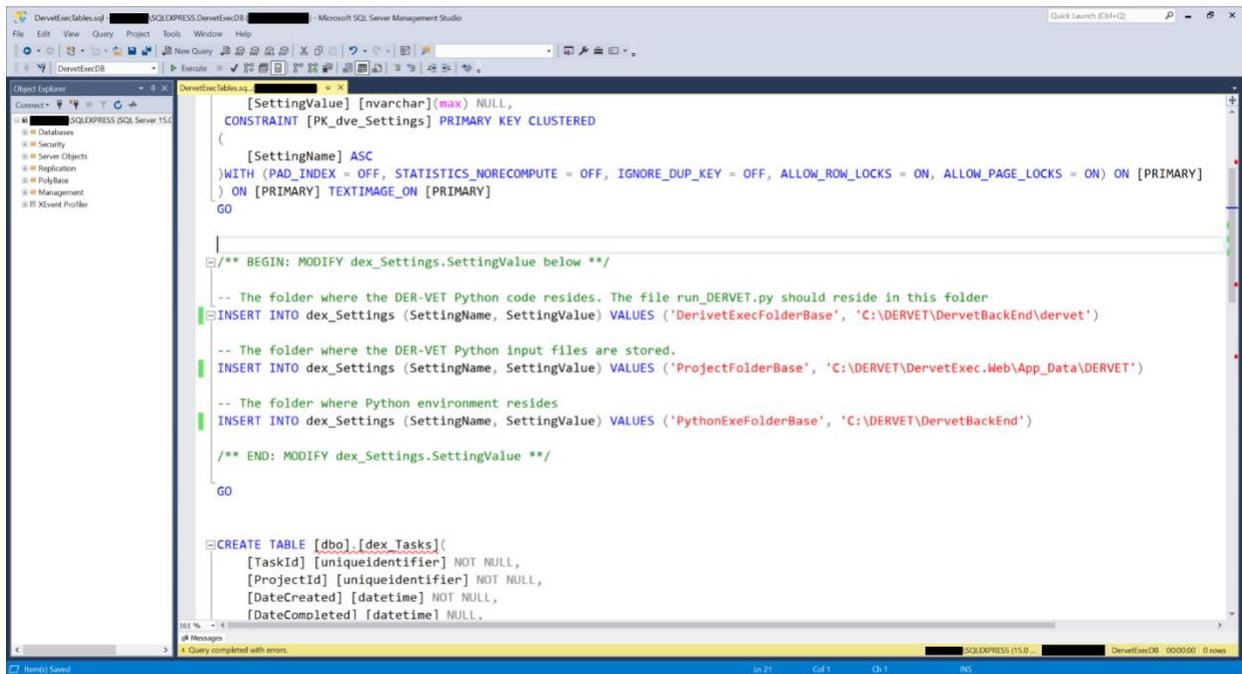
```
INSERT INTO dex_Settings (SettingName, SettingValue) VALUES
('ProjectFolderBase', 'C:\DERVET\DervetExec.Web\App_Data\DERVET')
```

```
INSERT INTO dex_Settings (SettingName, SettingValue) VALUES ('PythonExeFolderBase', 'C:\DERVET\DervetBackEnd')
```

You need to update the text within these three statements.

- Change the ...path to DER-VET software... placeholder to the folder name where you installed EPRI's DER-VET software, e.g. C:\EPRI\DERVET.
- Change the ... \DervetExec.Web\App\_Data\DERVET placeholder by replacing the ellipses with the folder where you installed the DervetExec.Web website. Leave the rest of the setting as-is, the \DervetExec.Web\App\_Data\DERVET part. When done, the setting should look something like C:\DERVET\DervetExec.Web\App\_Data\DERVET.
- Change the ...path to Python environment... placeholder to the folder name where the Python environment is installed, e.g. C:\DERVET\DervetBackEnd.

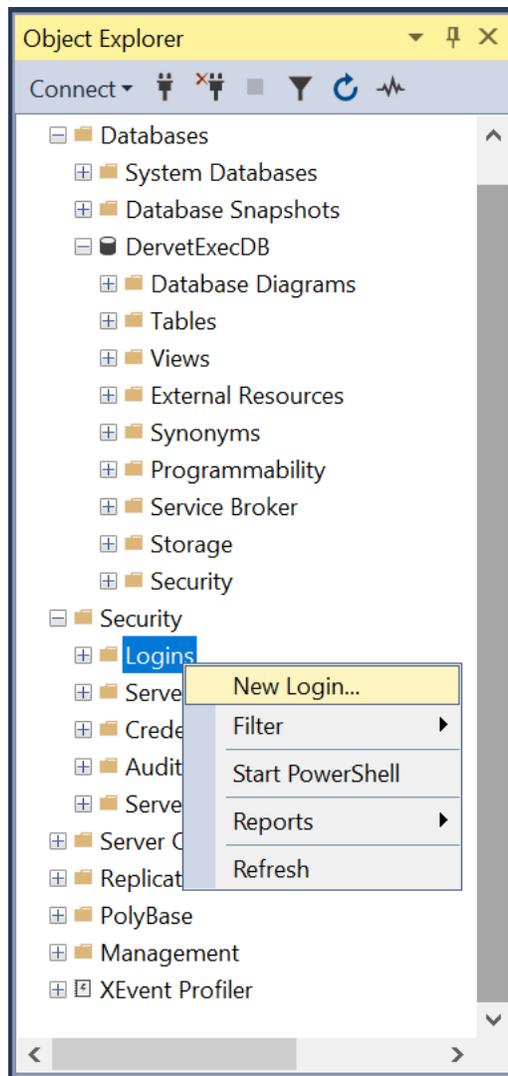
After updating these values, click the Execute button to execute the SQL script.



The DervetExec.Web website needs to be able to access the DervetExecDB database. To accomplish this, you must create an account in SQL Server for the security context under which the DervetExec.Web website runs. When you created the DervetExec.Web website you specified the Application Pool the website would run under. Unless you explicitly changed this, the Application Pool is named DervetExec.Web.

To grant the Application Pool DervetExec.Web access to the DervetExecDB database, perform the following steps:

7. From SQL Server Management Studio, expand the top-level Security folder. (Note that there is also a Security folder under each Database - it is imperative that you expand the top-level Security folder.)
8. Right-click on the Logins folder and choose New Login.



9. In Login name enter IIS APPPOOL\DervetExec.Web.

**Login - New**

Select a page

- General
- Server Roles
- User Mapping
- Securables
- Status

Script Help

Login name: IIS APPPOOL\DervetExec.Web Search...

Windows authentication  
 SQL Server authentication

Password:   
 Confirm password:   
 Specify old password  
 Old password:   
 Enforce password policy  
 Enforce password expiration  
 User must change password at next login

Mapped to certificate   
 Mapped to asymmetric key   
 Map to Credential  Add

Credential	Provider

Remove

Default database: master

Default language: <default>

OK Cancel

**Connection**

Server: [REDACTED] SQLEXPRESS

Connection: [REDACTED]

[View connection properties](#)

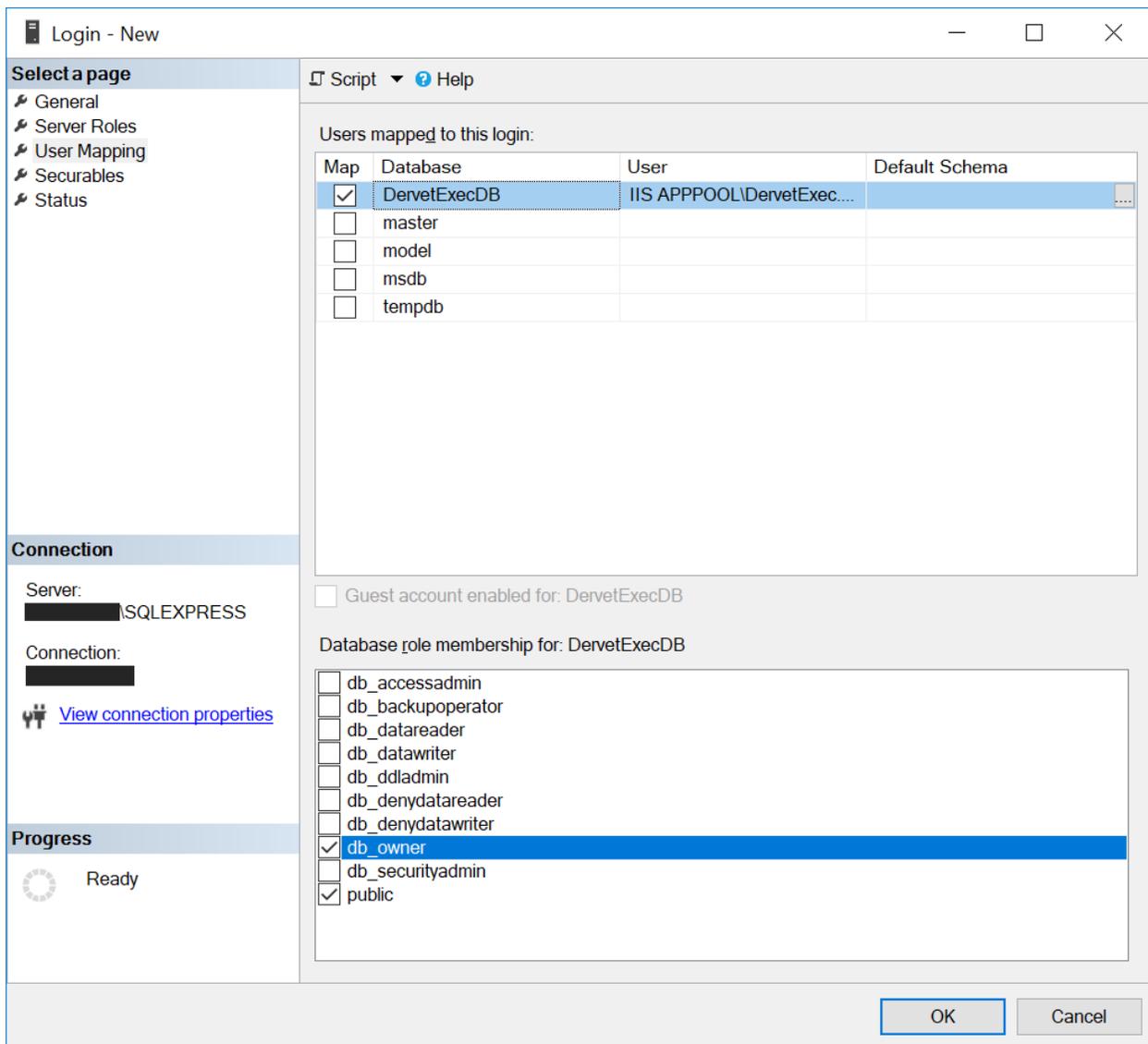
**Progress**

Ready

10. Click on the User Mapping page on the left.

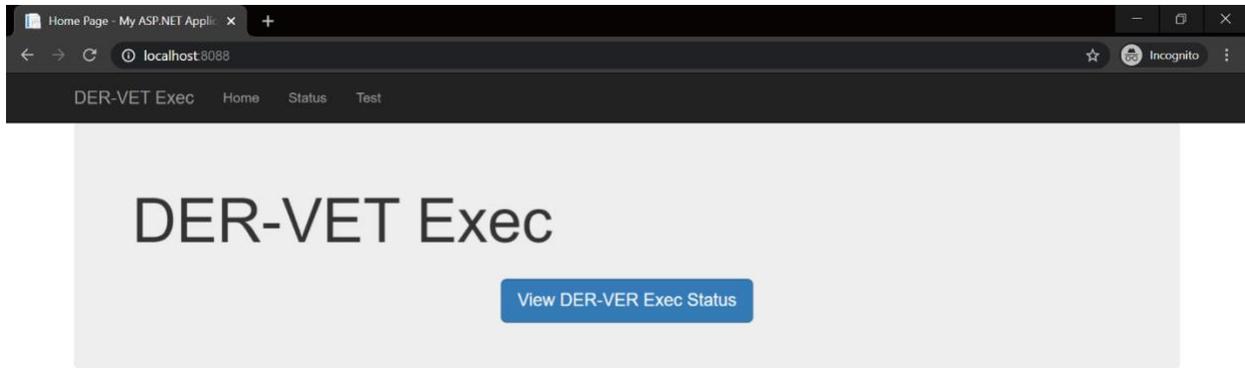
11. Check the DervetExecDB database in the top section. Once checked, review the Database role membership options in the bottom. Ensure that the db\_owner checkbox is checked.

12. Click OK.

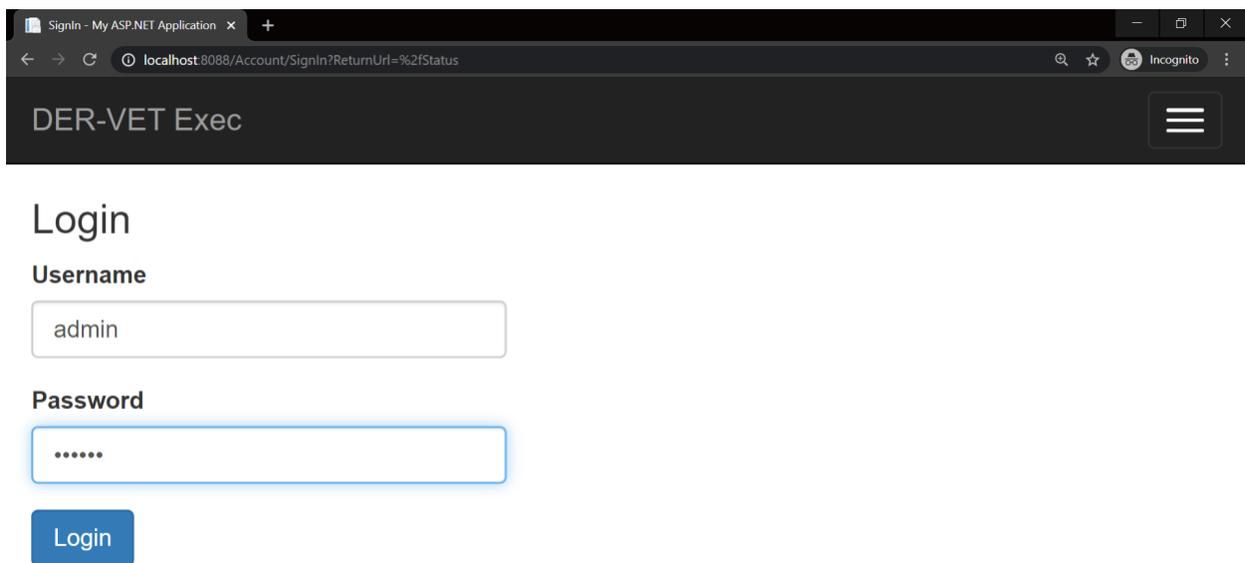


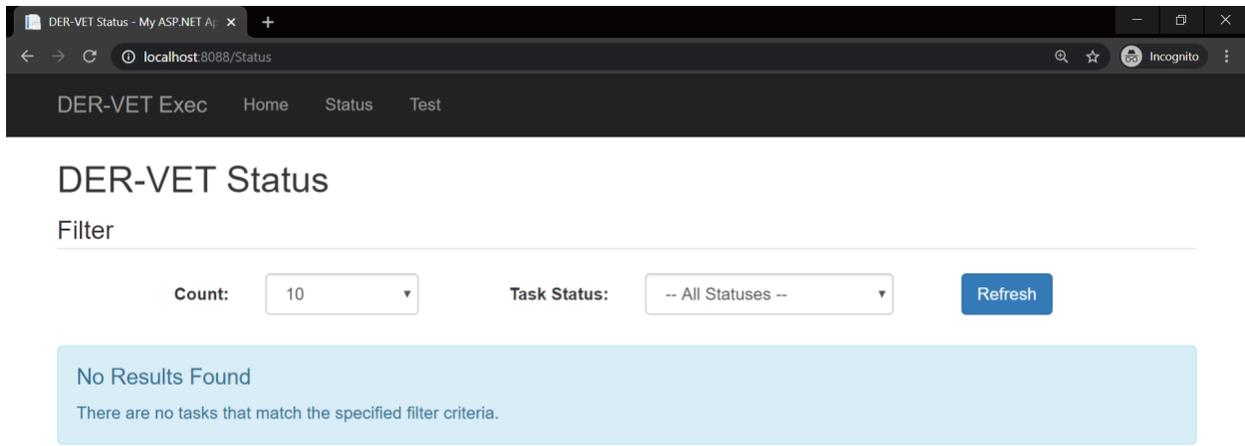
## Running DER-VET Community Edition

To test the installation and configuration, start by launching a web browser and visit the `DervetExec.Web` website. The URL for this website will depend on the port number you entered when creating the website in IIS. Say you used `8088` - in this case you would visit `http://localhost:8088`. You should see a message titled `DER-VET Exec` with a button labeled `View DER-VET Exec Status`. If you don't see this message or get some sort of error, that indicates that the `DervetExec.Web` website was not setup or configured properly.

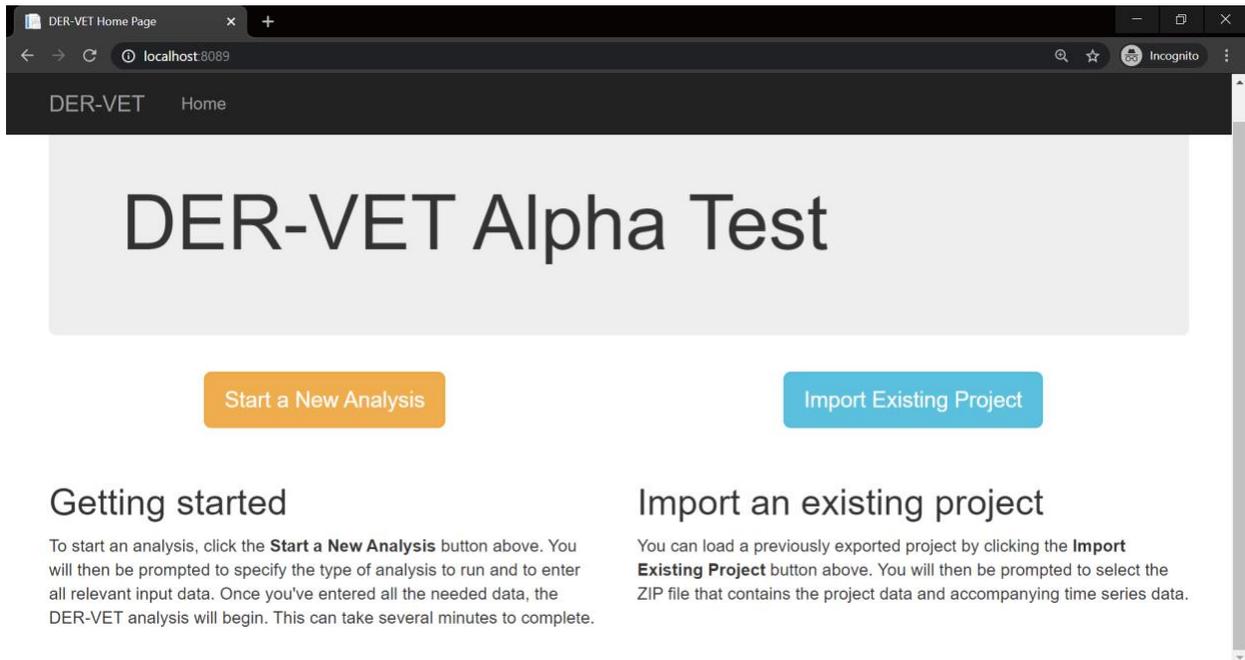


Click the View DER-VET Exec Status button. You should be taken to a login page. Here, enter the username and password specified in the `DervetExec.Web` website's configuration file. Once you've authenticated, you should see a screen that lists the DER-VET optimizations that have been run to date (which, at this point, will be none). If you get an error when viewing this page in particular, it likely indicates an issue with the database. Either the database was not installed or the security is not appropriately configured.





Next, visit the `DerivetUI.Web` website. The URL for this website will depend on the port number you entered when creating the website in IIS. Say you used `8089` - in this case you would visit `http://localhost:8089`.





### **Export Control Restrictions**

Access to and use of this EPRI product is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or U.S. permanent resident is permitted access under applicable U.S. and foreign export laws and regulations.

In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI product, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case by case basis an informal assessment of the applicable U.S. export classification for specific EPRI products, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes.

Your obligations regarding U.S. export control requirements apply during and after you and your company's engagement with EPRI. To be clear, the obligations continue after your retirement or other departure from your company, and include any knowledge retained after gaining access to EPRI products.

You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of this EPRI product hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

**The Electric Power Research Institute, Inc.** (EPRI, [www.epri.com](http://www.epri.com)) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together...Shaping the Future of Electricity