ENVERUS

June 15, 2022

POWER & RENEWABLES

EV ADOPTION IMPACT ON DISTRIBUTION NETWORKS

A Trickle Change in Charging

ANALYSTS

Rocky Ma
Associate
403.397.3333
rocky.ma@enverus.com

Juan Arteaga
Senior Associate
403.213.4417
juan.arteaga@enverus.com

Ryan Luther, CFA
Senior Vice President
403.536.4885
ryan.luther@enverus.com

FOCUS

Will increased stock of electric vehicles (EVs) and charging behavior threaten the stability of the North American power grid?

KEY POINTS

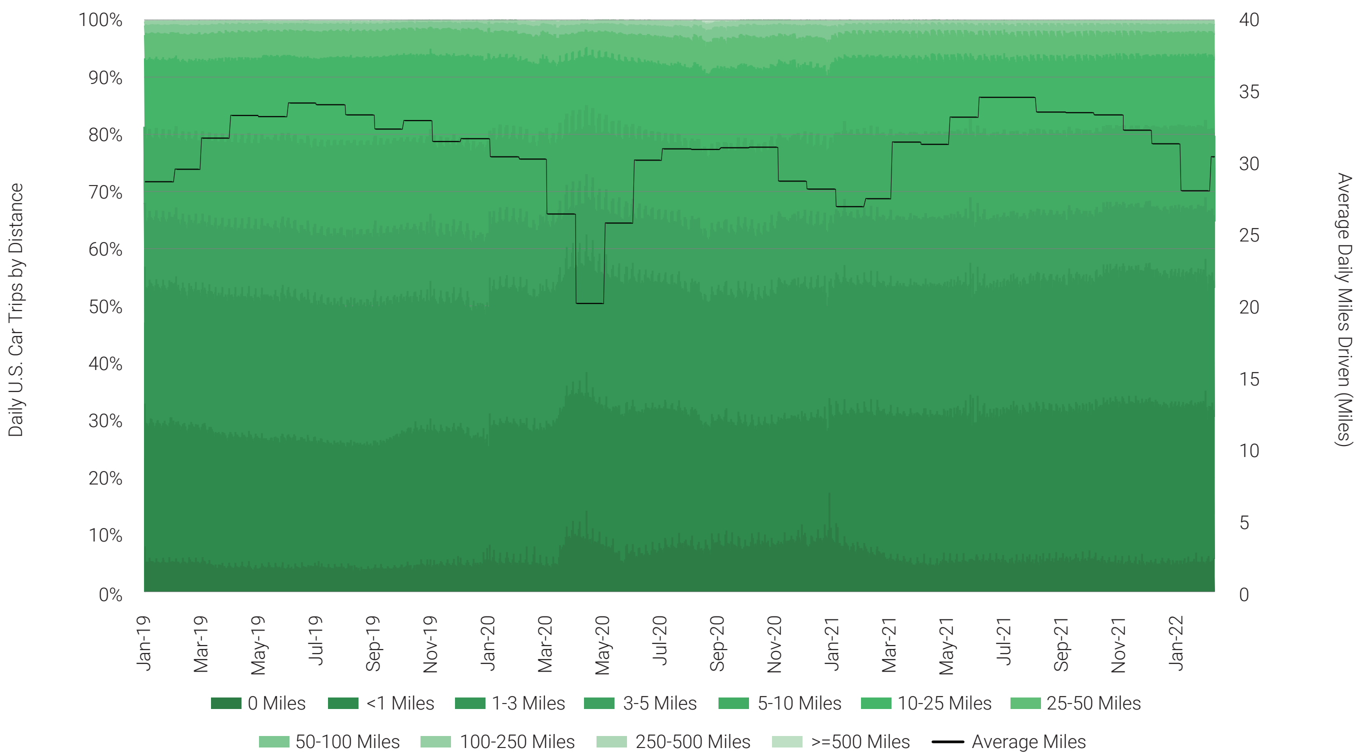
- While some speculate residential EV charging will destroy the grid, we think there won't be a significant impact until 2035 at the current rate of EV adoption.
- A typical neighborhood could require transformer upgrades with as little as 10% EV stock if owners use simple chargers with no timing features and all charge at the same time.
- Residential charging policies will play a critical role in ensuring EV adoption doesn't create grid reliability issues.
- Most neighborhoods won't require any upgrades until at least 70% EV adoption, assuming policy is put in place to ensure smart chargers are used.
- Household charging demand could naturally balance wind generation at night, when it's least needed.

GENERAL

Since some speculate that EV charging could overload the electrical grid, this report focuses on understanding the distribution grid impacts EV charging will have as adoption increases. This is done by analyzing the effects of charging behavior on a household's electrical demand profile.

According to the U.S. Bureau of Transportation Statistics, the average American household owns two vehicles and the average daily driving distance is 30 miles (**Figure 1**). For this report we assume each household owns two EVs, each requiring 6.9 kWh every day to replenish the charge used during the daily commute.

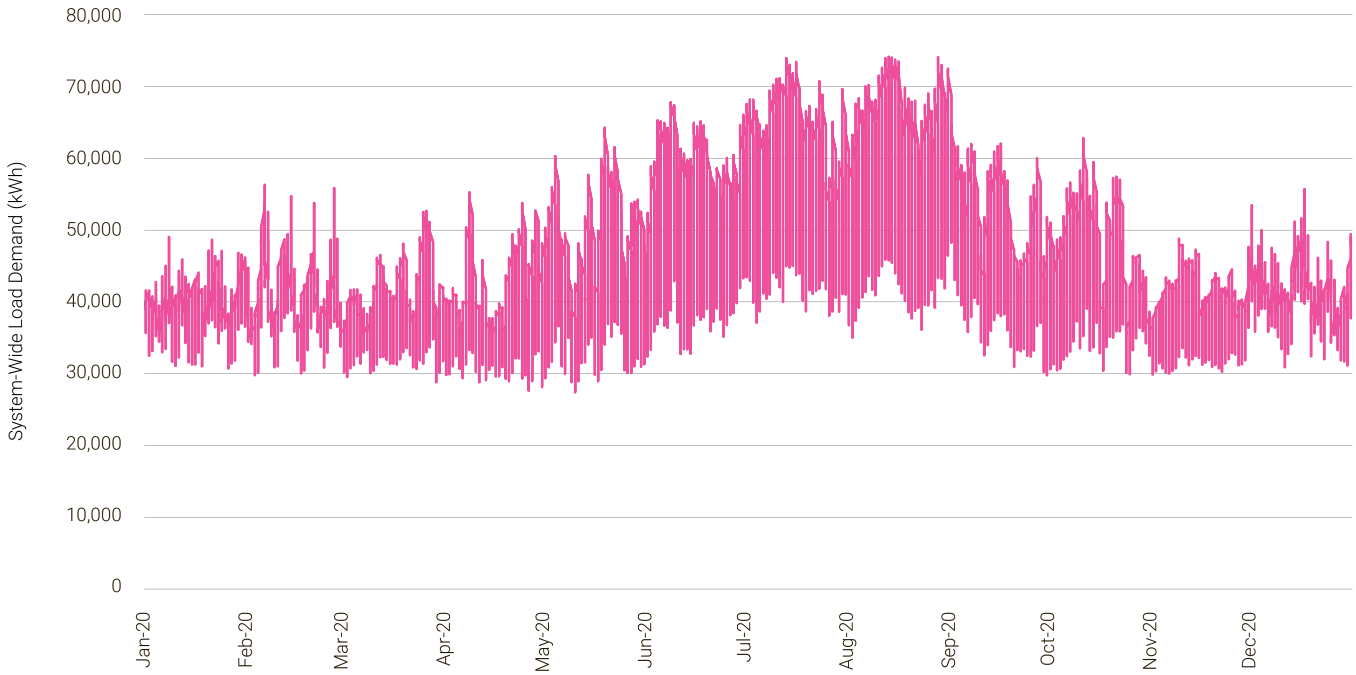
FIGURE 1 | U.S. Distribution of Neighborhood Transformers



Source | Enverus Intelligence, U.S. Bureau of Transportation Statistics

To calculate the worst-case load scenario, we analyze the months with the highest average temperature in a calendar year. Typically, electricity consumption peaks in summer months because of air-conditioning load (**Figure 2**). We consider a typical residential distribution network where the limiting component is the transformer. We assume a cluster of 20 houses with a unit power factor that is served by a single-phase pad-mounted 100 kVA transformer. The EV charger considered in this study is the Tesla Wall Connector model charger, recommended by Tesla for home charging use.

FIGURE 2 | Hourly Household Electricity Consumption With Varying Temperatures



Source | Enverus Intelligence, ERCOT

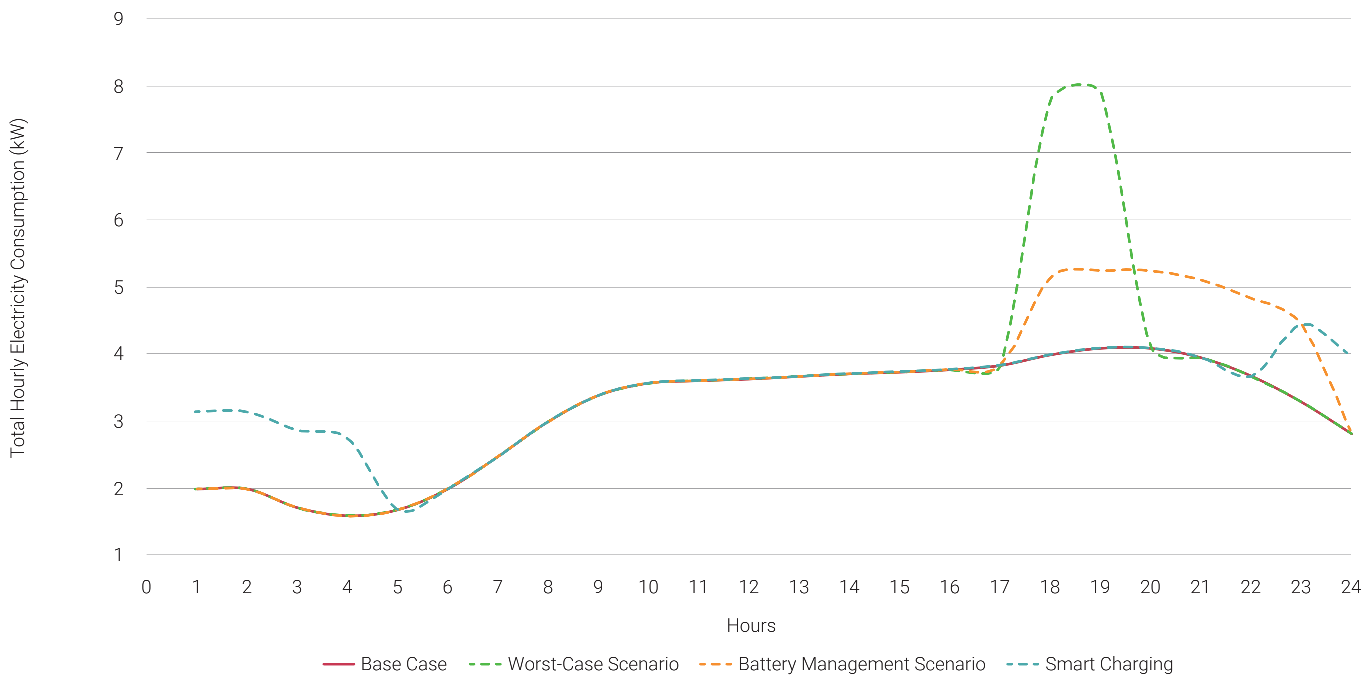
RESIDENTIAL LOAD PROFILE AND EFFECTS OF ADDING EV CHARGING

The base case shown in **Figure 3** represents the typical load profile for a single-family detached house during summer months in the U.S. This represents the hourly electricity consumption before the addition of an electric car. To analyze the impacts EV charging brings to the distribution network, three different charging behaviors by EV users are compared.

- **Worst-Case Scenario**: We assume EV owners have negligible battery management and perform charging during daily peak electricity consumption hours. Peak usage occurs around the time most people return home from work (i.e., 6 p.m.). It is also assumed that the EV chargers are set to fast charging mode, meaning that the maximum power will be drawn until the battery is completely charged.
- **Battery Management Scenario**: Vehicles are also set to charge during peak consumption hours. However, in this case we assume the battery does not need to be charged as soon as possible and split the total output of the EV charger over six hours, reducing the maximum power drawn at any given hour.
- **Smart Charging**: This scenario implements the concept of delayed charging, meaning charging is postponed until regular household electricity consumption is lower. Battery management principles are also applied as the charging is set to complete over a six-hour window.

Figure 3 shows the impact a single EV would have on the load profile for each charging scenario. Charging up the battery as soon as plugged in would almost double the peak consumption, while extending the charging time would only increase the peak load by 22%. Furthermore, extending and delaying the charging time would reduce that peak increase to only 8%.

FIGURE 3 | Household Daily Load Profile Scenarios



Source | Enverus Intelligence

At 12% EV stock, the transformer capacity of a typical neighborhood would be exceeded, resulting in an immediate impact and urgent need to upgrade its infrastructure. This situation is highly unlikely to occur as most modern EV charging models default to extended charging over six to eight hours, depending on a user's settings. A 12% stock in the typical neighborhood means that four of the 20 houses have one EV; this level of EV adoption already exists in some parts of the country without significantly impacting the distribution network.

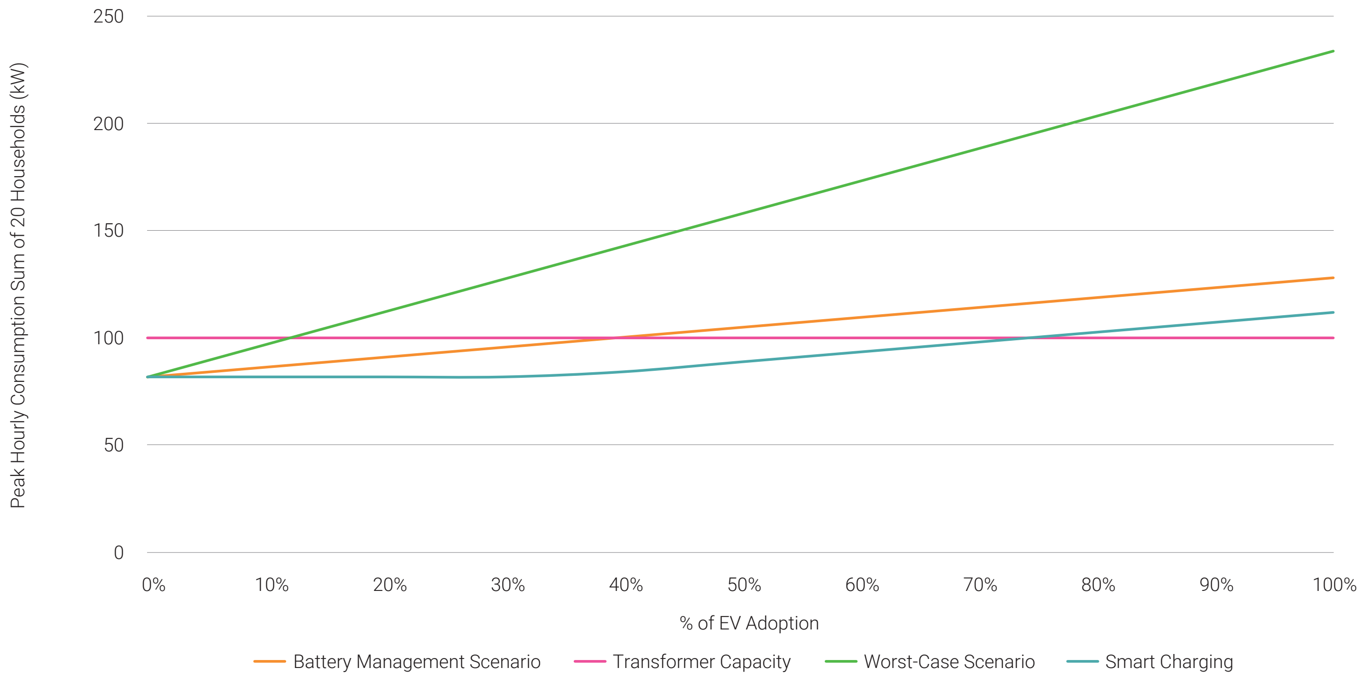
The extended charging scenario would become problematic at a 40% EV stock, meaning that 16 cars in this 20-house neighbourhood are fully electric and charging at coincident hours.

The smart charging scenario has the smallest impact to the grid and is the most supportive for EV adoption. A typical neighbourhood's peak load is not increased until EV stock surpasses 35%, since charging occurs outside of peak hours. EV adoption with smart charging would only become problematic when reaching 75% EV stock, which means every house has one EV, half have two and all charge at coincident hours.

From the data we can see that the addition of EV charging into the grid could result in capacity issues for residential households. However, the impacts of EV charging can be significantly reduced by implementing smart charging principles (**Figure 4**).

We believe it makes economic sense to implement smart charging mandates to avoid massive capital requirements to upgrade the distribution network to accommodate unnecessary fast charging behavior.

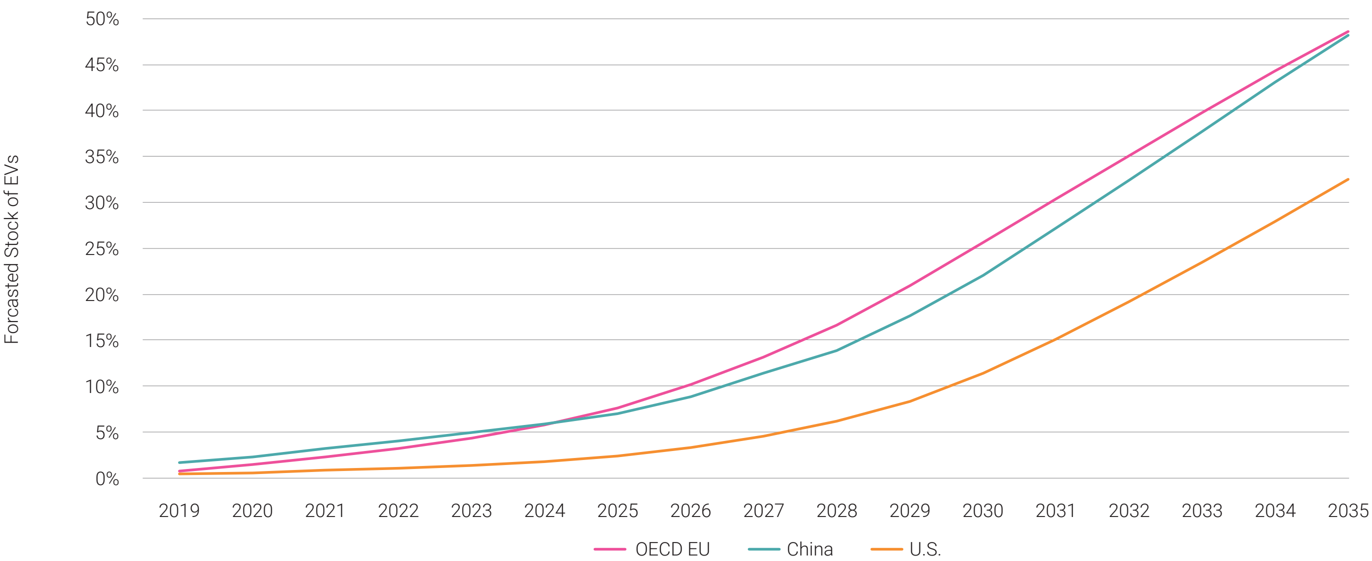
FIGURE 4 | Neighborhood Power Demand Scenarios at Varying EV Penetration Rates



Source | Enverus Intelligence

Although the results show that distribution networks at their current state could struggle to accommodate EV adoption, the issue is still far in the horizon. We can see in **Figure 5**, extracted from Enverus' **latest Oil Demand Update**, the forecast of the percentage share of EVs on the road in different regions of the world. We predict that sanctions on Russia will affect the nickel market globally, increasing battery prices and slowing down the EV adoption. The chart shows EV penetration in the U.S. won't surpass 15% until 2031 and EV stock won't reach 30% until 2035. Therefore, we believe it is highly unlikely that capacity concerns regarding EV charging will prove to be a significant issue in the near future.

FIGURE 5 | Forecast Stock of EVs



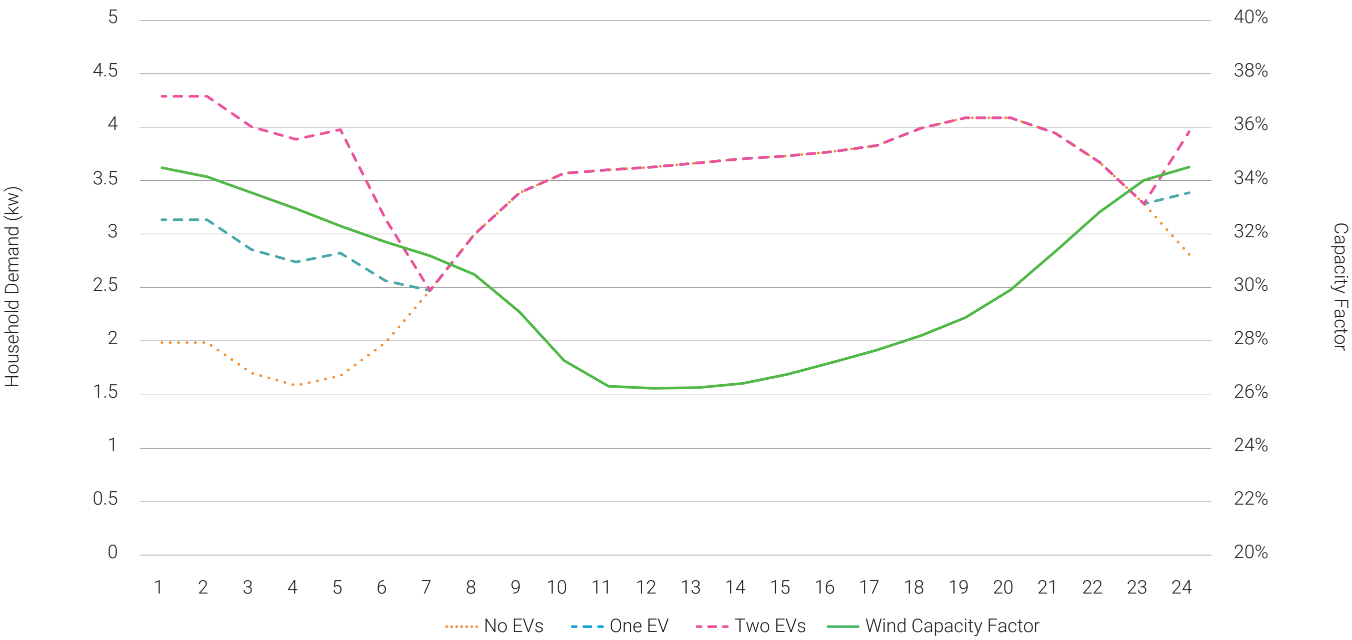
Source | Enverus Intelligence

EV CHARGING AND WIND ENERGY

Wind and solar generation are at the forefront of the energy transition. A major challenge with wind generation is excess energy production during the night when demand is low, which leads to clean energy curtailments. Implementing smart EV charging could be an effective way to utilize some of this excess renewable energy.

Figure 6 compares the average wind generation profile in the U.S. with the typical household demand profile at no, one and two EVs per household, assuming a smart charging policy is in place. Increased wind generation at night is partially offset by the demand for EV charging, allowing for a higher mix of wind generation without the need for storage or curtailments.

FIGURE 6 | Hourly Wind Generation Profile and Household Demand Profile



Source | Enverus Intelligence

Enverus Intelligence™ | Research Disclosure Statement:

The material in this report is the property of Enverus Intelligence Research, Inc. ("EIR") unless otherwise indicated. All trademarks, service marks and logos used in this report are proprietary to EIR or Enverus. This report is provided solely to clients of EIR. Furthermore, this report is proprietary, confidential and provided for the exclusive use of the recipient and may not be redistributed to or shared with any individual, company or entity outside of your organization without the express prior written consent of EIR.

The material presented in this report is provided for information purposes only and is not to be used or considered as a recommendation to buy, hold or sell any securities or other financial instruments. Information contained herein has been compiled by EIR and prepared from various public and industry sources that we believe to be reliable, but no representation or warranty, expressed or implied is made by EIR, its affiliates or any other person as to the accuracy or completeness of the information. Such information is provided with the expectation that it will be read as part of a mosaic of analysis and should not be relied upon on a stand-alone basis. Past performance should not be taken as an indication or guarantee of future performance, and we make no representation or warranty regarding future performance. The opinions expressed in this report reflect the judgment of EIR as of the date of this report and are subject to change at any time as new or additional data and information is received and analyzed. EIR undertakes no duty to update this report, or to provide supplemental information to any client receiving this report.

To the full extent provided by law, neither EIR nor any of its affiliates, nor any other person accepts any liability whatsoever for any direct or consequential loss arising from any use of this report or the information contained herein. The recipient assumes all risks and liability with regard to any use or application of the data included herein.

EIR provides custom research to its clients which are distributed on different frequency schedules. Custom research reports may provide different depths of analysis and more frequent updates based on levels of service and fees selected by clients.

No EIR directors, officers or employees are on the Board of Directors of a subject company and no one at a subject company is on the Board of Directors of EIR. EIR does not invest in any securities or manage any securities portfolios. Therefore, it would have no investment relationship with a subject company. Furthermore all employees are subject to restrictions on trading in energy company securities. The views expressed in this report accurately reflect the research analyst's personal views about the subject securities. EIR analysts are compensated from overall firm revenue only and are not compensated to express any view about an issuer or from proceeds derived from any particular transaction between EIR or any of its affiliates and an issuer.

Enverus and its affiliated companies, including EIR, serve over 6,000 customers globally and is reasonably likely to have received compensation for products or services in the preceding twelve months from any company mentioned in this report.

These disclosures apply to any and all supporting materials provided with this report, including but not limited to NAV or other models.

Equity owners of Enverus include affiliated entities of Hellman & Friedman and Genstar Capital, each of whom separately sponsor and manage private investment funds and may make investments in, or otherwise seek to do business with, a company or companies covered by this report. EIR has adopted and implemented policies and procedures reasonably designed to maintain the independence of its research coverage in an attempt to mitigate any potential conflict of interest related to such activities.

Valuation and Methodology

EIR valuations are based primarily on calculations of net asset value (NAV), which are derived using discounted cash flow (DCF) models. The NAV model begins with an evaluation of a company's proved developed reserves using industry-standard decline analysis. EIR then assesses the company's land holdings using a variety of technical data sources (geology, completion, historical production, etc.) to estimate the viability of the acreage for future drilling. Each well has an associated capital and operating cost structure that is incorporated into EIR's model, which also accounts for hedges, debt, taxes, general and administrative costs, and other corporate-level financial inputs. EIR typically runs a number of sensitivities around key variables, such as well cost, reserves and commodity prices, to show the range of possible outcomes.

Note to U.K. Persons

EIR is not an authorized person as defined in the U.K.'s Financial Services and Markets Act 2000 ("FSMA") and the content of this report has not been approved by such an authorized person. You will accordingly not be able to rely upon most of the rules made under FSMA for the protection of clients of financial services businesses, and you will not have the benefit of the U.K.'s Financial Services Compensation Scheme. This document is only directed at (a) persons who have professional experience in matters relating to investments (being 'investment professionals' within the meaning of Article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 (the "FPO")), and (b) High net worth companies, trusts etc of a type described in Article 49(2) of the FPO (all such persons being "relevant persons"). EIR's services are available only to relevant persons and will be engaged in only with relevant persons. This report must not be acted or relied upon by persons who are not relevant persons. Persons of a type described in Article 49(2) of the FPO comprise (a) any body corporate which has, or which is a member of the same group as an undertaking which has, a called up share capital or net assets of not less than (i) in the case of a body corporate which has more than 20 members or is a subsidiary undertaking of an undertaking which has more than 20 members, £500,000 and (ii) in any other case, £5 million, (b) any unincorporated association or partnership which has net assets of not less than £5 million, (c) the trustee of a high value trust within the meaning of Article 49(6) of the FPO and (d) any person ('A') whilst acting in the capacity of director, officer or employee of a person ('B') falling within any of (a), (b) or (c) above where A's responsibilities, when acting in that capacity, involve him in B's engaging in investment activity.