Energy Efficiency and Cost Saving Opportunities for Asphalt Mixture Production

An ENERGY STAR® Quick Guide for Managing Energy

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The cover photo is of the Port Manatee plant in Palmetto, Florida, courtesy of Ajax Paving.

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Introduction: Energy Management is Good for Your Business

Effective energy management helps a company keep costs down and stay competitive. The U.S. Environmental Protection Agency (EPA), through the ENERGY STAR program, has observed that a well-run energy program can reduce energy costs by 3% to 10% annually, as well as reduce waste and emissions, which are costly.

Companies can differ in the amount of energy they use even when they belong to the same industry, operate under the same market conditions, and use the same equipment.

High performing organizations:

- actively manage energy,
- adopt a structured approach to energy management,
- establish policies and procedures for long-term results,
- have senior management's support,
- allocate staff and resources,
- establish goals,
- develop management structures that empower staff to address energy efficiency issues directly, and,
- build a culture of continuous improvement.

Sound, plant-wide energy management combined with energy-efficient technologies offer additional benefits, such as improved product quality, increased production, and process efficiency. As part of a company's overall environmental strategy, energy efficiency improvements often lead to reductions in emissions of greenhouse gases (GHGs) and other air pollutants.

This *Quick Guide* provides basic information to identify cost-effective practices and technologies for reducing energy use throughout a company's operations. It focuses on the most important systems, equipment, processes, and practices that account for the bulk of energy consumption in asphalt mixture production.

1 Where is Energy Used?

Knowing where energy is used in a plant is an important first step in managing energy.

1.1 Asphalt Mixture Production

In its most basic terms, asphalt mixture production involves the heating and mixing of aggregates with asphalt binder. Asphalt binder (also asphalt cement, liquid asphalt, or bitumen) is a viscoelastic material produced during crude oil refining. The asphalt binder is heated to reduce its viscosity enough to coat dry aggregates and bind the aggregates together, forming a durable asphalt pavement material (asphalt concrete or bituminous concrete) when it cools.

Asphalt mixture is produced via these steps.

1. Aggregate conveyance. Aggregates, including stone and sand of various coarseness, are loaded into individual cold feed bins. A specified amount of selected aggregate types drops onto a conveyor running below the bins and feeds aggregates into a large rotating drum.

2. Aggregate drying. A large burner flame on one end of the drum generates hot gas that flows through the drum to dry and heat the aggregate. As the drum rotates, flights, specially shaped lifters mounted to the inside of the drum, pick up aggregate from the bottom of the drum and then shower the aggregate through the hot burner gases to maximize the exposure of aggregate surface area to the hot air and facilitate aggregate drying and heating to appropriate mixing temperature.

3. Mixing. Asphalt binder is pumped from heated storage tanks and mixed with the dry, hot aggregate. Mixing differs by plant type.

    a. In continuous flow plants, the aggregate and asphalt are mixed continuously. After the aggregate has been dried and heated to mixing temperature, the aggregate and asphalt binder are mixed within the drying drum's mixing zone or in a separate mixing drum or pugmill mixer. The mixed product can then be conveyed into storage silos or surge bins. There are two kinds of continuous flow plant designs: parallel flow and counter flow. In a parallel flow plant, aggregate and heated air move in the same direction, starting in the drying drum nearest the burner and advancing to the end opposite the burner. In a counter flow plant, the aggregate and heated air move in opposite directions, with the aggregate entering the drying drum opposite the burner, and proceeding through the drum toward the burner, before dropping out into a separate mixing chamber. Because of its superior thermal efficiency and lower emissions, counter flow is the dominant technology for new plants sold in the U.S.

    b. In batch plants, the dry aggregate is conveyed to the top of the batch tower via a bucket elevator system, screened to re-separate by size, and stored in hot bins until a batch-specific mix is dispensed into the pugmill and combined with the asphalt binder. In this configuration, if the hot bins become full because the aggregate gradations fed into the plant differ from the aggregate gradations used for the mix, the hot aggregates in full bins may be discharged, wasting the heat that was used for drying and heating the aggregate. The mixed product can either be loaded directly into trucks or conveyed into storage silos.

c. When materials such as reclaimed/recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS) are included in a paving mix, they are added during the mixing stage. Virgin and RAP/RAS materials are fed in separate streams, and heat from the virgin materials indirectly heats and dries the RAP and RAS to create a blended mix. Indirect heating of RAP is necessary to avoid excess emissions and maintain quality of the asphalt binder. Incorporation of RAP in asphalt plants is usually limited by the plant's ability to efficiently transfer heat from virgin aggregates to heat and dry the RAP.

d. The amount of RAP/RAS materials used for a given application is a function of plant equipment/technologies, customer specifications, and local availability of RAP/RAS. The national average use of RAP has risen from 15% in 2009 to 22% in 2021 (NAPA 2022a). In limited circumstances, incorporating RAP can displace up to 100% of the virgin aggregate and asphalt binder otherwise needed (Shacat 2019), though these applications require specialized plants that are designed and equipped to address operational limitations associated with high RAP content. Through another process referred to as Cold Central Plant Recycling, asphalt mixtures can be produced at ambient temperatures with up to 100% RAP.

A discussion of other factors affecting production, including warm-mix asphalt production and more details on the inclusion of RAP, follows in section 4.

An overview of production is shown in Figures 1-3.

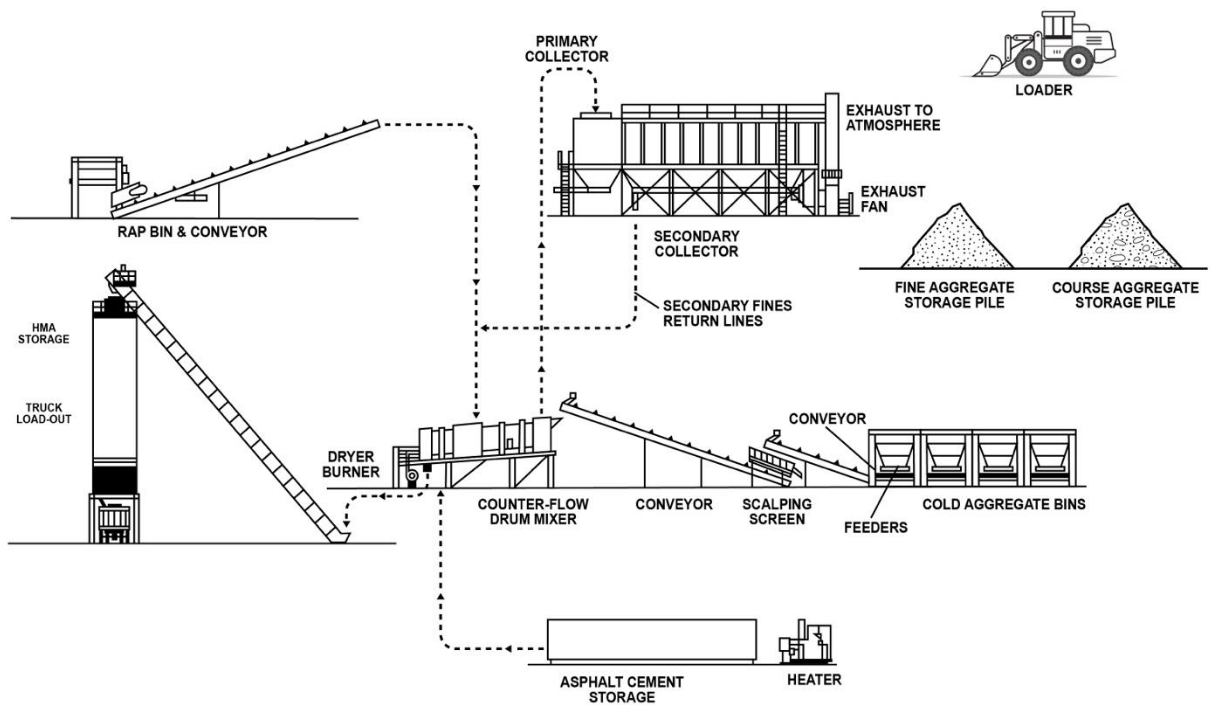

Figure 1. Asphalt mixture production in a counter flow continuous plant

Diagram based on U.S. EPA's AP-42 Section 11.1, Figure 11.1-3.

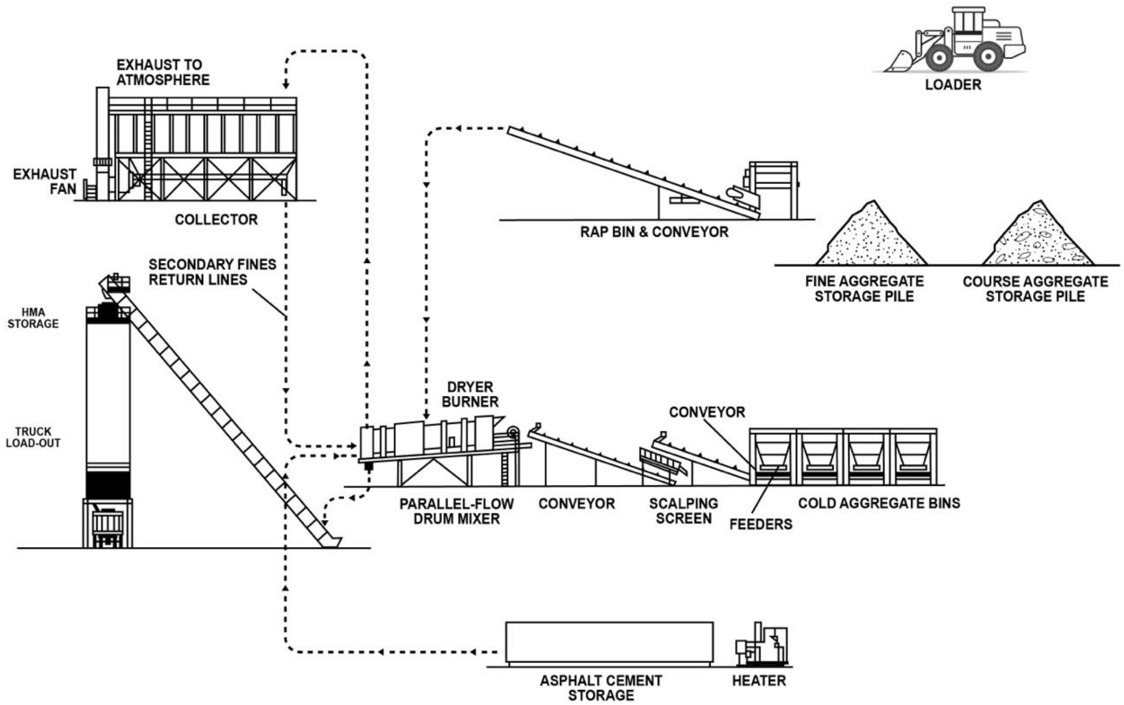

Figure 2. Asphalt mixture production in a parallel flow continuous plant

Diagram based on U.S. EPA's AP-42 Section 11.1, Figure 11.1-2.

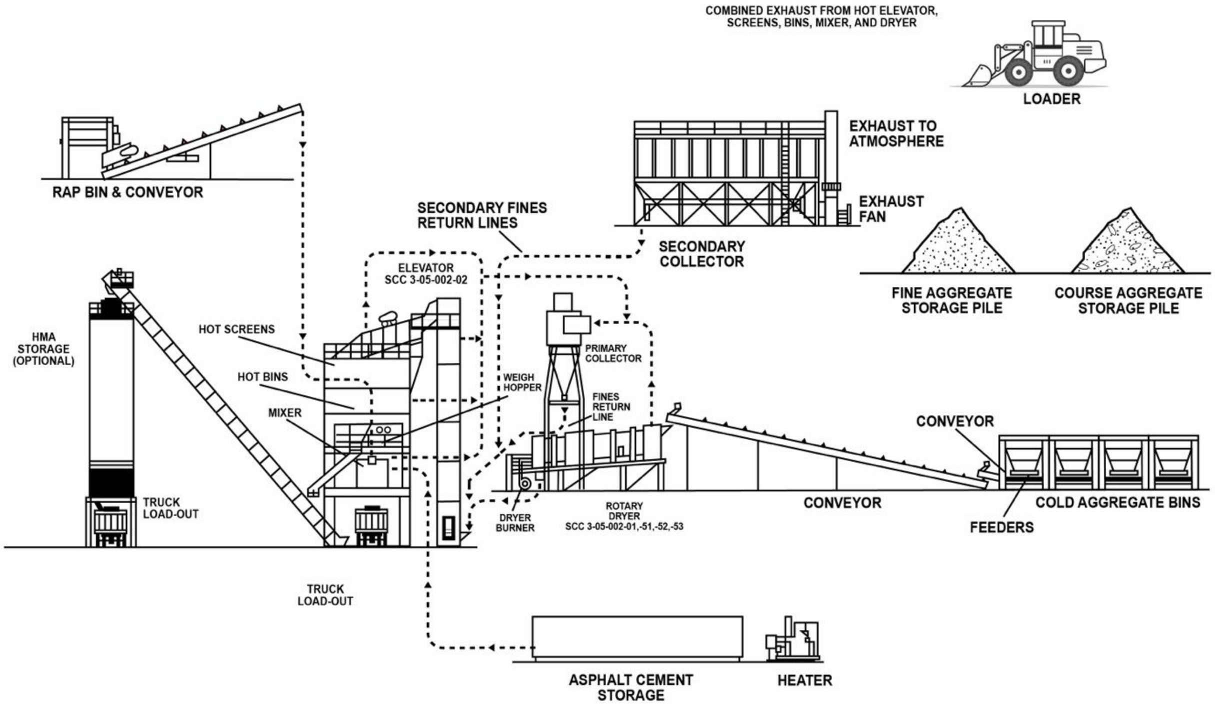

Figure 3. Asphalt mixture production in a batch plant

Diagram based on U.S. EPA's AP-42 Section 11.1, Figure 11.1-1.

1.2 Energy Use

Asphalt mixture production is energy intensive. The most significant energy centers are drying aggregate, heating stored asphalt binder and mixed asphalt, and for the electricity needed to run motors for the production process (NAPA 2023).

- Fuel use for aggregate drying. The largest use of fuel in the plant is the aggregate drying burner, which is matched to the plant's production and baghouse capacity to ensure an efficient system. Some burners are designed for up to 200 MMBtu/hour heat output for plants designed at up to 700 tons/hour capacity, but during normal operation would operate below peak capacity (Ramsey 2021, Swanson 2021). The smallest plants, with a rated capacity of approximately 60 tons/hour, have substantially smaller burners. Factors affecting fuel consumption include:
    - Production rate, both in terms of how closely the plant is running compared to design capacity, and how consistently that production is maintained throughout the production shift.
    - Veiling efficiency, or the efficacy of aggregate distribution across the face of the drum to contact hot gases, given the configuration of flights and specifications for the site's typical range of mixes.

- Moisture content and temperature of incoming aggregate and RAP/RAS.
- Required temperature of asphalt mix. The temperature requirement is affected by whether RAP/RAS will be added to the mix, whether warm-mix technologies are being used, and the presence of specialized additives such as polymers.
- Required temperature of dry aggregate. The shares of virgin aggregate and RAP/RAS in the final mix, as well as the required mix temperature, will determine how hot the dry aggregate needs to be before leaving the drying drum. Hot-mix asphalt typically requires aggregate temperatures ranging from approximately 300°F for 100% virgin mixes up to 800+°F for mixes with a high percentage of RAP (Swanson 2021).
- Required temperature of exhaust gas. For dust collection, exhaust gas entering the baghouse must always remain above the dewpoint to avoid moisture problems in the baghouse, with the goal of staying very near the dewpoint to minimize energy waste. Baghouse temperature is affected by the type of aggregate dryer: parallel flow exit gas temperature usually is 310-330°F, and counterflow exit gas temperatures can be as low as 180°F though they usually need to be controlled to 220-240°F for baghouse requirements (Brock (no date)). This is affected by ambient air leakage into the system and air introduced for baghouse filter cleaning.
- Ambient air infiltration, including air leakage through drum seals, flop gates, and duct work connections.
- System insulation, including dryer, baghouse, and ductwork.
- Location, including elevation, ambient temperature, and relative humidity.

* **Fuel use for hot-oil heater.** Hot-oil systems are typically used to heat the liquid asphalt binder prior to mixing, though a new innovation involves heating binder tanks, silos, piping, and drag conveyors using only direct electric heating. For asphalt mixtures, the liquid asphalt binder is heated to at least 325°F to reduce its viscosity enough to coat aggregates. Factors affecting the fuel consumption include:
    - System insulation on liquid asphalt binder silos, piping, hot oil lines, flanges, and jumpers.
* **Electricity use for motors.** The most important motors used in the asphalt mixture plant include:
    - A baghouse exhaust fan driven by one larger motor or a combination of smaller motors.
    - The drying/mixing drum's rotation driven by one large motor or multiple smaller motors.
    - A burner blower driven by one motor.
    - A main drag conveyor driven by one motor.
    - Small motors used for material handling (elevators, conveyors, pumps).
    - Air compressors.

According to a June 2016 life cycle assessment commissioned by NAPA, the total process energy needed to produce asphalt mixture averages 317.096 MJ per ton. This is comprised of 96% non-electricity energy (289,000 Btu) and 4% electricity (3.32 kWh). Detailed calculations and statistical analysis are available in the source report (Mukherjee 2016). Charts showing the process energy consumption and cost were developed by Joseph Shacat, NAPA, based on these source data and are depicted in Figures 4 and 5.

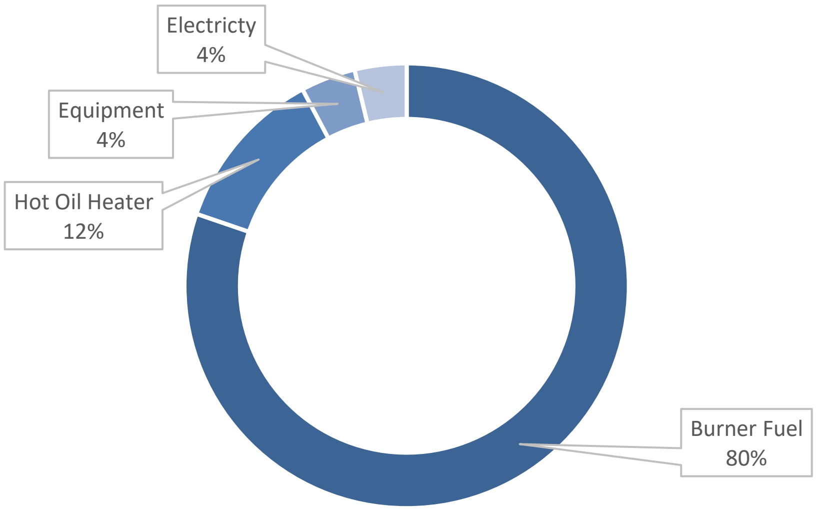

Figure 4. Energy breakdown in a typical asphalt mixture production plant

Source: Shacat 2021

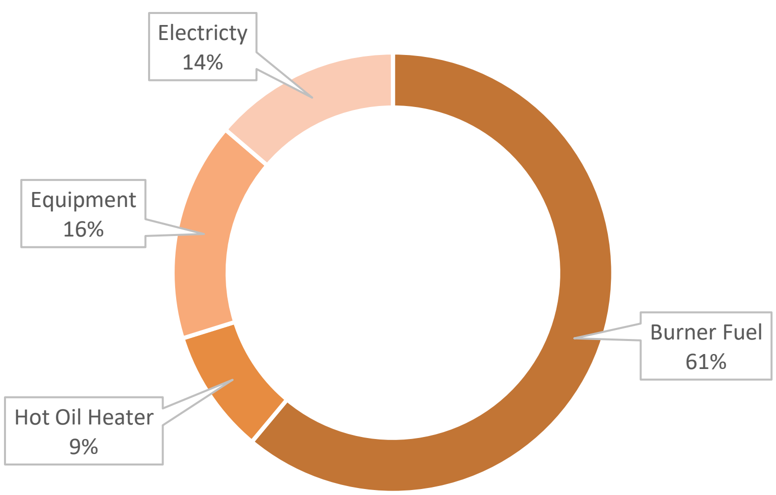

Figure 5. Energy cost breakdown in a typical asphalt mixture production plant

Source: Shacat 2021

2 Managing Energy Use

An organization-wide energy management program is the best way to save energy and money. EPA offers tools and resources to help you build a strategic energy management program. All resources can be found at www.energystar.gov/industry.

ENERGY STAR® energy management resources

EPA's ENERGY STAR® Guidelines for Energy Management provides a basic energy management structure that is easy to follow.

Another ENERGY STAR guide, Teaming Up to Save Energy, outlines how to form an energy team within your organization and assign roles and responsibilities for managing energy.

2.1 Effective Principles for Energy Savings

For success, apply these basic principles. Any company of any size can do it!

- **Make energy a priority.** *Everyone* in the company, *including senior management,* must recognize that reducing energy use is an important business objective that must be part of decision making.
- **Commit to save energy.** Every level of the organization must support a commitment to improve energy efficiency.
- **Assign responsibility.** Someone must be assigned responsibility for managing energy. An energy team, with roles assigned to each member, is a practical way to share the load.
- **Look beyond first cost.** You get what you pay for. Energy-efficient equipment and products may cost more initially but the long-term savings will surpass the initial cost. Use a return-on-investment analysis to inform capital purchase decisions.
- **Make energy management a continuous process.** Successful energy management goes beyond installing a few energy-efficient light bulbs. Build a company-wide energy program and make energy one of the top items managed by the business.
    - Understand your energy use.
    - Set goals.
    - Put in place good operations and maintenance practices.
    - Encourage behavioral changes.
    - Track and benchmark energy use.
    - Engage every employee.

EPA works with companies to identify the basics of an effective energy management program by using the *ENERGY*

STAR Guidelines for Energy Management.[1] To assess how your company manages energy, use *ENERGY STAR's Energy Program Assessment Matrix*. Figure 6 shows the main steps to form an energy program. Easy tools to get energy management started at a site are EPA's *ENERGY STAR Facility Assessment Matrix* and *ENERGY STAR Small/Medium Manufacturer Energy Management Assessment Matrix*.

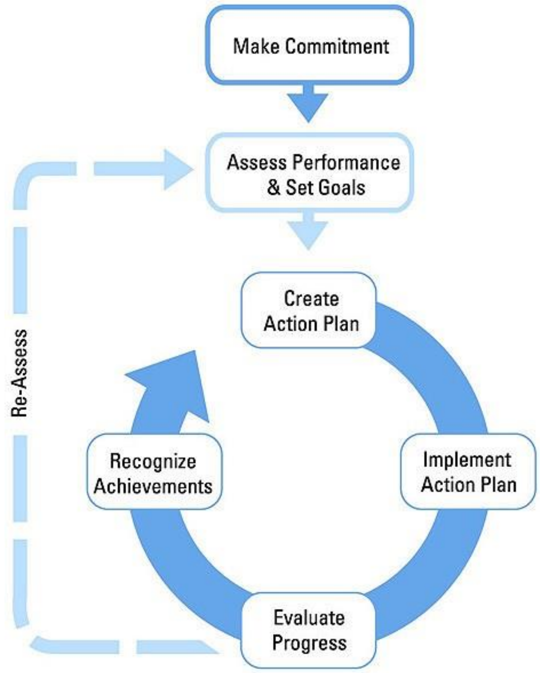

Figure 6. Elements of strategic energy management, ENERGY STAR Guidelines for Energy Management

2.2 Elements of the Energy Management Process

Four key elements contribute to the energy management process: (1) energy assessments, (2) energy teams, (3) employee awareness, and (4) energy monitoring.

Plant Energy Assessments

Plant energy assessments determine where and how much energy is consumed, and identify steps to improve the facility's energy efficiency and save money. The assessment can focus on the whole site or specific systems and processes.

Assessments can be conducted by company staff, the local electric and gas utility, contractors, or government programs.

- **Staff teams.** If company employees perform the plant assessment, team up the plant's operators with other staff from across the company. This brings together a spectrum of experience and knowledge of the plant and its processes. Facilities of any size can successfully use this method. EPA, through ENERGY STAR,

[1] Increasingly, organizations are integrating energy management efforts into broader sustainability programs. Download NAPA's Sustainable Asphalt Pavements: A Practical Guide.

provides guidance for one such type of assessment, the Energy Treasure Hunt (see http://www.energystar.gov/treasurehunt for more information). During Energy Treasure Hunts, diverse teams walk the plant and collaboratively identify no- and low-cost operational and behavioral changes that will improve energy performance.

- **Electric and Gas utility programs.** Local utility companies work with their industrial clients to achieve energy savings in existing facilities and in the design of new facilities. Check with your local electric and gas utility to see what assistance it provides. Utilities sometimes offer specific programs for improving plant systems such as lighting, motors, or boilers, and may include rebates or other financial incentives.

- **Federal government programs.** The U.S. Department of Energy (DOE) supports plant assessments through the Industrial Assessment Center (IAC) program. IACs are designed to help small- and medium-size enterprises. Universities that participate in the program offer no-cost technical assessments, performed by engineering students and faculty, and subsequently provide a report identifying opportunities for improving performance and leveraging applicable rebates and financial incentives.

Energy Teams

People in your company make decisions affecting energy use every day. Creating an energy team helps to coordinate those decisions to actively manage energy. In addition to planning and implementing specific improvements, the team measures and tracks energy performance and communicates with management, employees, and other stakeholders.

The size of the energy team will vary depending on the size of your organization. In addition to the company's energy director who leads the team, consider including each plant's operator and a representative from each operational area that significantly affects energy use (e.g., engineering, purchasing, operations and maintenance, building/facilities management, environmental health and safety, corporate real estate and leasing, construction management, contractors and suppliers, and utilities). For more information on forming an Energy Team, see *Teaming Up to Save Energy*.

Employee Awareness

Everyone has a role in energy management. Effective programs make employees, managers, and other key stakeholders aware of energy performance goals and initiatives, as well as their responsibility in carrying out the program.

Most people are unaware of how their everyday actions and activities at home and work influence energy use and impact the environment. Increasing overall awareness can be an effective way to gain greater support for energy initiatives. Opportunities to increase awareness include new employee orientation programs, poster campaigns, Earth Day events, intranet and internet sites, energy fairs or summits, regular campaigns designed to engage

Educated, empowered employees identify and achieve energy savings

Engage employees and operators in the energy program, especially the assessments, projects, and day-to-day decisions. An effective energy-awareness campaign:

- Educates employees and operators on how their work practices affect the company, energy use, costs, and the environment,
- Informs employees on how they can manage energy in their day-to-day responsibilities, and,
- Reminds employees about the company's energy goals.

employees, and opportunities to gain recognition for energy-saving ideas and accomplishments. Energy Treasure Hunts can also offer broader engagement opportunities for employees by giving them greater exposure to energy use challenges and best practices they can adopt in their daily activities.

Individuals working in or even managing a facility may have little understanding of the energy performance of the facility or its impact on the organization and environment. Targeted efforts designed to increase awareness of facility energy use can help build support for energy management programs. Facility-oriented energy awareness may include sharing data on energy costs and environmental information, sources of energy, the amount of energy used by certain equipment, etc. More detailed operational information may include job-specific training, scorecards tracking actual performance against best-practice targets for specific equipment and processes, benchmarking across a company's sites, and statistical benchmarking across an entire industry using tools like the ENERGY STAR Energy Performance Indicator and the ENERGY STAR Portfolio Manager.

Increasing energy awareness of managers can help to build support for energy management initiatives. Approaches for gaining management support include identifying key decision makers, tailoring information to their focus (e.g., cost of energy per unit of product), determining the most effective ways to communicate, and maintaining regular contact. For more details on these opportunities and approaches, see the ENERGY STAR Guidelines for Energy Management.

ENERGY STAR employee awareness resources

EPA's ENERGY STAR offers a variety of ways to communicate energy efficiency and tools to engage with employees. One popular example is the ENERGY STAR Challenge for Industry, a goal setting and achievement recognition tool. The Challenge for Industry is a good way to engage employee teams and recognize site-level energy intensity improvements.

Energy Monitoring Systems

Every company should compile, track, and benchmark energy data. Reliable energy data helps a company manage energy, interpret energy efficiency trends over time, and take corrective action when necessary. Data on energy use can be found in utility bills, fuel purchase receipts, or from meters.

In addition to tracking purchased energy, using an energy monitoring system is ideal. It requires minimal up-front capital and can result in immediate savings. Energy monitoring systems include submeters at key areas in a plant to strategically track and manage energy. Submetering different production areas provides improved metrics and enables quick pinpointing of areas where energy problems may occur. The meters' data should be managed with a data management tool; a simple spreadsheet may be sufficient, or tailored software is also available that can help identify problems and savings.

In its simplest form, an energy tracking system should be based on:

- Monthly utility billing and energy-use data for the past 12 to 24 months.
- Monthly production figures.

Using a simple spreadsheet, both can be plotted in graphs to understand the relationship between energy use and production and to identify any trends. For example:

- Graph of energy use and production over time.
- Graph of energy costs and production over time.
- Graph of energy use on vertical axis against production on horizontal axis.
- Graph of energy use divided by production unit (showing specific energy consumption).

Tools offered within commonly used spreadsheet packages can help to identify relationships and quantify trends. Graphs can be made for fuel and electricity separately, as well as for total energy use (showing both in the same units, such as megajoules or British thermal units) and costs. EPA developed a basic Energy Tracking Tool for companies and sites to use to track energy.

More sophisticated approaches include monitoring via dashboards for the plant operator to quickly identify how changes to operational settings affect energy consumption in real time. Other approaches will integrate production characteristics that affect the efficiency of a plant's performance. For the asphalt pavement industry, this includes factors such as weather, moisture content of the aggregate, percentage of design capacity utilized, and amount of RAP and RAS included in the mixture. Production can be normalized for these factors, enabling energy managers to assess what changes in performance are beyond the site's control, and which need to be addressed. Often the analysis will show periods of good performance and poor performance; this information helps a company set targets for energy consumption based on expected production volumes.

Tracking energy use by entering new data and evaluating it regularly will help identify problems and improve energy savings. Energy monitoring provides data useful for corporate greenhouse gas accounting initiatives. Successful monitoring programs regularly – daily, hourly, or in real time – report energy use to identify increased use and costs that could be caused by operational inefficiencies. Energy monitoring and metering systems also help companies to participate in emergency demand response programs, in which utility companies provide financial incentives to customers who reduce their energy loads during peak demand times.

3 Where to Improve Energy Efficiency in Asphalt Mixture Production: Common Plant Systems

This section identifies key ways to control energy use in common plant systems.

3.1 Lighting

Lighting is not a big part of electrical consumption in asphalt plants, but energy-efficient lighting can give substantial savings.

Cost-effective measures to save on lighting energy are discussed below.

Did you know?

Only a small part of the energy used in a lighting fixture results in lighting. Much is lost as heat. Install energy-efficient lighting.

Use LED lighting. Light emitting diode (LED) lights are the latest generation of energy-efficient lighting. The long lifetime of LEDs and reduced maintenance costs generally make a strong business case for LED lighting. Specific applications need to be evaluated in terms of sensitivity to thermal and electrical conditions, light distribution, lamp color, lumen maintenance, glare, dimmability and restrike issues, ballast noise, durability, and flicker.

There is a wide variety of LED lighting products that can be used in industrial facilities, including some compatible with current linear and low- and high-bay light fixtures. Although many products outperform their counterpart linear fluorescent, high wattage fluorescent, metal halide (MH) and high-pressure sodium (HPS) lighting systems, their efficiency and performance vary widely. The following two paragraphs address the main two types of LED applications in industries, based on Department of Energy's Lighting Facts Database (ended March 2018).

Replace linear fluorescent lights with LED lights. Linear LED lamps, also known as TLEDs, can replace linear fluorescent fixtures and reduce power use for lighting by up to 60%. Due to significant variations among different LED products, the impact their use can have on illumination levels and energy consumption should be carefully evaluated. Significant energy savings can be achieved when LED lighting systems with efficacies on the highest range (95th percentile) are adopted.

Replace high wattage fluorescent, metal halide and high-pressure sodium lights with LED lights. Industrial plants are replacing all existing lighting technologies with LEDs for both interior and exterior applications. Facilities are replacing fluorescent lights with LEDs in both low-bay (ceilings less than 20 feet high, typically 15,000 to 20,000 lumens per fixture) and high-bay (ceilings more than 20 feet high, typically 15,000 to 100,000 lumens per fixture) applications. Many industrial LED lights now emit the same lumens and have higher efficacies than high-wattage fluorescent, MH and HPS, offering the opportunity to improve the lighting quality and level while still saving energy. Retrofitting existing fluorescent fixtures with either ballasted or non-ballasted LED tubes may offer a lower cost alternative, with similar energy savings.

Case study: LED lighting

Titan America, a cement and ready-mixed concrete producer, installed 10 LED fixtures instead of high-intensity discharge (HID) fixtures on a beltline. HID fixtures, which needed more time to switch on, had remained on during the night for employees to check equipment. With the installation of LED fixtures characterized by "instant on" and the use of light-switch timers, the lights now burn only 250 hours instead of 4,000 hours per year. This resulted in higher than anticipated savings in electricity of about $50 per fixture per year (Bayne 2011).

If replacing linear fluorescent lights with LEDs is not feasible for your application, then consider **replacing T-12 tubes with T-8 or T-5 tubes** (~30% energy savings) and **replacing magnetic ballasts with electronic ballasts** (12-30% energy savings, and up to 50% longer life).

Use occupancy sensors and other lighting controls. Automatic controls, such as occupancy sensors, turn off lights when a space is unoccupied. Manual controls can save additional energy in smaller areas. Numerous case studies throughout the United States suggest that the average payback period for occupancy sensors is approximately 1.5 years.

Upgrade exit signs. Exit signs may be used in on-site support buildings such as offices, QC labs, and maintenance facilities. Switching from incandescent lamps to LEDs or radium strips in exit sign lighting reduces electricity use by about 90%. The lifetime of an LED exit sign is about 25 years, compared to one year for incandescent signs, which can reduce exit sign maintenance costs.

3.2 Motors

Motors are the biggest consumer of industrial electricity. They are used in many areas, such as conveying materials, HVAC, compressed air, dust collectors and pumps. When considering energy efficiency improvements to a facility's motor systems, take a "systems approach," focusing not simply on the motor but on the entire motor system (the motor; driven equipment such as pumps, fans, and compressors; and controls).

Did you know?

Up to 95% of a motor's costs come from the energy consumed over its lifetime, while only about 5% of a motor's costs come from its purchase, installation, and maintenance (MDM 2007).

A systems approach for motors includes the following steps:

1. Locate and identify all motors in the facility.
2. Document conditions and specifications of each motor to provide a current systems inventory.
3. Assess the needs and actual use of motor systems to determine whether motors are properly sized and how well each one meets the needs of its driven equipment.
4. Collect information on potential repairs and upgrades to the motor systems, including economic costs and benefits of implementing repairs and upgrades, to help with decision-making.
5. If upgrades are pursued, monitor the upgraded system's performance to determine actual cost savings.

Case study: Efficient motors

CEMEX (formerly RMC Pacific Materials) had 13 worn and inefficient motors in cement blowers and silo pumps. Using DOE's MotorMaster+ software tool, plant personnel identified causes of inefficiency (DOE 2005). New, more efficient motors yielded 2 million kWh energy savings and $168,000. Annual savings in maintenance costs came to $30,000.

Tips: Motor System Energy Efficiency Measures

Develop a motor management plan	A motor management plan can help companies realize energy savings and ensure that system failures are handled quickly and cost-effectively. When motors fail, plants may default to the quickest and lowest cost option, but a motor management plan helps personnel evaluate options including replacement or rewinding.2
Select motors strategically	Analyze the life-cycle costs rather than just the initial purchase and installation costs. Up to 95% of a motor's lifetime costs come from the energy it consumes over its lifetime, while only about 5% of its costs come from its purchase, installation, and maintenance (MDM 2007).
Select energy-efficient motors	Selecting energy-efficient motors is an important strategy for reducing motor system life-cycle costs. With proper installation, energy-efficient motors can run cooler (which may help reduce facility cooling loads) and have higher service factors, longer bearing life, longer insulation life, and less vibration.
Maintain your motors	Motor maintenance prolongs motor life and anticipates possible failures. Savings from an ongoing motor maintenance program can range from 2% to 30% of total motor system energy use. Follow manufacturer guidance on maintaining your motors.
Ensure motors are properly sized	A wrong-sized motor leads to unnecessary energy losses. Replacing oversize motors with properly sized motors saves U.S. industry, on average, 1.2% of total motor system electricity consumption.
Consider automating motor shutdown	Automatic shutdown of motors that otherwise would be left idling can reduce energy costs without requiring high investment. According to plant assessments from Titan America, a 25 hp non- automated motor, running unloaded for 5 hours per day, costs about $1,000 annually (Bayne 2011).
Consider variable frequency drives (VFDs)	Variable frequency drives (VFDs) conserve electrical energy on motors, such as large fan motors by slowing the fan instead of using dampers to restrict air flow. They can be easily retrofitted to any existing asphalt mixture plant. Energy savings may vary from 7% to as high as 60%, depending on the use pattern of the motor. Opportunities for VFDs include exhaust fan motors, burner blower motors, feed bin motors, drag slat motors, bucket elevator motors, drum drive motors (assuming appropriate flighting), pump motors, and air compressors.

[2] If rewinding, select shops that follow the practices described in the current ANSI/EASA AR100: Recommended Practice for the Repair of Rotating Electrical Apparatus.

3.3 Compressed Air

Compressed air is often the most expensive form of energy used in an industrial plant because of its poor efficiency. The use of compressed air should be limited to the minimum quantity for the shortest possible time, constantly monitored, and weighed against alternatives. Many energy reduction options for compressed air systems are not prohibitively expensive. Payback periods for some are extremely short, often less than one year.

Common uses for compressed air in asphalt mixture production plants are in jet pulse baghouses, and in silo gates or other pneumatically operated plant components.

Case study: Air leak repair

O&G Industries, a construction and materials supplier in the Northeast, partnered with a consultant to conduct compressed air leak detection surveys focused on the facility's compressed air generation and delivery components. The survey used ultrasonic leak detection to locate and quantify compressed air leaks throughout the facility and tag them with the leak's decibel reading. The survey identified 30 leaks totaling 78.2 CFM of lost air. The facility established a goal of repairing 75% of leaks, equaling potential savings of 39 MWh/year and $4,700, and a simple payback of just over 1.5 years. With utility incentives, adjusted payback was 0.8 years (O&G Industries 2023).

Tips: Compressed Air Energy Efficiency Measures

Maintain compressed-air systems	Inadequate maintenance can lower compression efficiency, increase air leakage or pressure variability, and can lead to increased operating temperatures, poor moisture control, and excessive contamination of compressed air system components. The following maintenance activities will reduce these problems and save energy: • Implement a compressed air leak management program. • Inspect and periodically clean filters to keep the compressor and intercooling surfaces clean and foul-free. • Keep motors and compressors properly lubricated. • Inspect fans and water pumps regularly to ensure proper performance. • Inspect drain traps periodically to ensure they are not stuck in the open or closed position and are clean. • If using compressors with belts, check the belts for wear and adjust them. Check water cooling systems for water quality (pH and total dissolved solids), flow, and temperature. • Specify pressure regulators that close when failing. • Applications requiring compressed air should be checked for excessive pressure, duration, or volume.

Reduce leaks in pipes and equipment	A typical plant that has not been well maintained will likely have a leak rate equal to 20% to 50% of total compressed air production capacity (U.S. DOE and CAC 2003). Leak maintenance can reduce this number to less than 10%. Minimizing leaks can generate immediate savings and avoid capital investment required to supplement compressed air system capacity. The best way to detect leaks is with an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. After being identified, leaks should be tracked, repaired, and verified. Leak detection and correction programs should be ongoing efforts, and integrated into regular compressed air maintenance activities.
Turn off unnecessary compressed air	Air should be turned off completely to equipment no longer using compressed air. This can be done using a simple solenoid valve.
Use compressed air storage tanks or receiver tanks	Where system demand is regularly below peak, size the compressed air system for the lowest consistent operating pressure demand, and add air storage tanks or receiver tanks to meet the intermittent peak demand.
Controls	A control strategy ensures that only the right amount of compressed air, at the right time, is generated and used in the production system. To determine proper control systems, assess compressed air requirements over time to establish a load profile. When demand is less than peak, use compressors with VFDs, or use multiple smaller compressors with sequencing controls, to improve system efficiency. Facilities with a flat load profile can use simpler control strategies.

3.4 Dust Collectors

To ensure proper operation of dust collectors, regularly inspect pulse air jets, mechanical shakers, bags and cartridges. Fabric bags must be sized correctly and fitted properly, and all worn fabrics should be replaced (MEMS 2010).

- Optimize **exhaust gas temperature**. Asphalt mixture plants often maintain exhaust gas temperatures 70-90°F above dewpoint to avoid the risk of condensation in the baghouse. This approach uses more fuel to keep the temperature high, and more electricity because hotter air is less dense and thus requires more revolutions of the exhaust fan to move an equal volume of air. Options for maintaining exhaust gas temperatures closer to the dewpoint include:
    - **Automate drum speed** to maintain the target exhaust gas temperature for the baghouse. Using a variable frequency drive for this application can reduce fuel consumption because it varies the rotational speed, thereby altering the volume of aggregate veiling across the drum cross section (Swanson 2020). For a related discussion of how flight configurations affect veiling efficiency and thus exhaust gas temperatures, see “Reduce exit gas temperature” in section 4.1.
    - Use a small, **secondary burner** to reheat exhaust gas before it enters the baghouse. This approach enables the plant to optimize the primary burner and drum for plant demand, and then

use a small burner (1-2 MMBtu/hour) to heat the exhaust gas to the target temperature (Hawkins).

- Consider using **real-time moisture sensors** to determine the current dewpoint and adjust operations to align exhaust gas more closely with the dewpoint (Swanson 2020).

Case study: Baghouse supplemental burner

Maxam offered an example of a continuous flow plant that, when optimized for demand, would have an exhaust gas temperature of 140°F. The secondary burner is then used to increase the exhaust gas temperature to 180-200°F instead of reducing the veil in the drum to permit more hot gas to flow directly into the baghouse. Maxam estimated this configuration could save 12% on fuel consumption and 20% on electricity (Hawkins 2020).

- Consider a **reverse air rotary baghouse**, which runs lower velocity air across a larger filtering area. The lower velocity air requires a lower horsepower motor, and the system avoids using compressed air for pulsing (Lavenberg 2020; ALmix 2021). However, because the larger volume of air necessitates adding 15% or more ambient air, then higher-temperature exhaust gas is needed to assure the mixed air still exceeds the dewpoint (Hawkins 2020).

- **Check seals in dust collector system,** as the existence of leaks will increase draft requirements. These include drum seals (especially exhaust end), duct work connections, baghouse doors, flop gates at feed chutes, and mix discharge flop gate.

- Employ the **minimum effective draft**. Extra draft will accumulate more dust on the filters, increasing wear of ducts and bags. Use variable-speed fans to control the draft.

- **Automate dust collectors** so they do not operate unless needed. Idle them or shut them down during non-production periods.

- **Resize and slow down fans that are too big**. This will result in energy savings. Installing a VFD will require highercapital investment but will result in increased energy savings. Dust fan size should be aligned with drum size, burner capacity, and baghouse size so that all operate as an integrated system. Baghouses for counter flow continuous plant types typically need about 167 actual cubic feet per minute (acfm) of exhaust volume capacity per ton per hour of plant production capacity, while batch plants need significantly larger baghouses because of additional scavenge air and steam volume produced by drying RAP in the mixing chamber upon mixing with hot virgin aggregate (Swanson 2021).

- **Maintain a differential pressure** across the dust collector (pressure difference between the dirty and clean side of the bags) between 3 to 4 inches of water (Swanson 2021). For efficient operation of dust collectors, filters should have a dust cake consistent with a differential pressure above 2 inches of water (Swanson 2021).

- Use a **differential pressure control system** to automate the cleaning system (i.e., pulse interval for pulse jet baghouse systems). Differential pressure should range between 4 and 5 inches of water when a fan-driven dust collector is used.

- A compressed air jet-pulse cleaning system should use the **minimum effective pressure**, which usually ranges between 60 and 70 psi, and not more than the manufacturer's recommended pressure.
- Employ a **rather short pulse** (~0.25 seconds) to shake extra dust off in the case of compressed air blowdown systems.

4 Energy Efficiency Opportunities for Asphalt Mixture Production Processes

The measures below address the energy efficiency of practices, processes, and technologies used specifically in U.S. asphalt mixture production plants. Most energy in plants is used for drying aggregate, heating stored asphalt cement and mixed asphalt, and motors (NAPA 2023). A variety of energy and material efficiency measures are discussed that can yield substantial cost savings while increasing or maintaining plant throughput, and in some cases, improving product quality.

4.1 Aggregate Handling, Drying and Heating

Significant energy savings are realized when the water content of coarse and fine aggregates is kept low, reducing the amount of drying needed. For every 1% change in moisture content, energy requirements change by 10% (NAPA 2023). Specific measures follow.

Did you know?

For every 1% change in moisture content, energy requirements change by 10%.

Energy savings from reduced aggregate moisture

% Moisture Before Change	% Moisture After Change																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
1.0	0%																		
1.5	8%	0%																	
2.0	15%	7%	0%																
2.5	21%	14%	7%	0%															
3.0	26%	19%	13%	6%	0%														
3.5	30%	24%	18%	12%	6%	0%													
4.0	34%	29%	23%	17%	11%	6%	0%												
4.5	38%	33%	27%	22%	16%	11%	5%	0%											
5.0	41%	36%	31%	26%	21%	15%	10%	5%	0%										
5.5	44%	39%	34%	29%	24%	20%	15%	10%	5%	0%									
6.0	47%	42%	37%	33%	28%	23%	19%	14%	9%	5%	0%								
6.5	49%	45%	40%	36%	31%	27%	22%	18%	13%	9%	4%	0%							
7.0	51%	47%	43%	38%	34%	30%	26%	21%	17%	13%	9%	4%	0%						
7.5	53%	49%	45%	41%	37%	33%	29%	25%	20%	16%	12%	8%	4%	0%					
8.0	55%	51%	47%	43%	39%	35%	31%	28%	24%	20%	16%	12%	8%	4%	0%				
8.5	57%	53%	49%	45%	42%	38%	34%	30%	27%	23%	19%	15%	11%	8%	4%	0%			
9.0	58%	55%	51%	47%	44%	40%	36%	33%	29%	26%	22%	18%	15%	11%	7%	4%	0%		
9.5	60%	56%	53%	49%	46%	42%	39%	35%	32%	28%	25%	21%	18%	14%	11%	7%	4%	0%	
10.0	61%	58%	54%	51%	48%	44%	41%	37%	34%	31%	27%	24%	20%	17%	14%	10%	7%	3%	0%

Figure 7. Energy savings potential from reducing aggregate moisture

Source: NAPA 2007

Provide shelter. The energy requirement to dry aggregates with a typical water content of 5% is around 23 lb of steam/hour per short ton of aggregate. When water content doubles, the steam requirement increases to 39 lb of steam/hour per short ton of aggregate; an increase of almost 70% (Stamper 1979). Thus, storing aggregates under shelter can lead to significant energy savings (Stamper 1979, Ang 1993). NAPA estimates that the cost

Did you know?

A one-inch rainfall over a 100-foot by 100-foot stockpile area adds 26 tons of water that will need to be drained or dried.

of building a structure to cover stockpiles will pay for itself within three years. Cover materials often consist of metal or fabric, and are designed to minimize internal, vertical supports that would impede loader access. CRH Americas Materials estimates that cover prices range from $5-15 per square foot, excluding freight and installation.

Consider orienting the storage areas to take advantage of the sunlight or the direction of prevailing winds to maximize free drying.

Create paved and sloped areas to place stockpiles. Aggregates are often stockpiled on the ground without precautions for water drainage, resulting in high water content, especially at the base of the pile. For example, when the area beneath the stockpiles in an asphalt-mix plant was paved and inclined, aggregate moisture content decreased by nearly 2% (Simmons (no date)), resulting in nearly 30% less drying (Stamper 1979). Additional benefits accrue as fewer raw materials are wasted to ground loss (3% material savings). Fuel is saved as well, as less is required for mobile equipment when storage areas are paved. The corresponding payback period for a paved and sloped storage area was estimated to be less than seven months (Simmons (no date)).

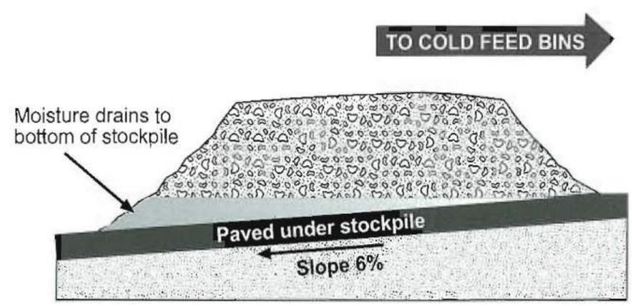

Figure 8. Paved storage under a stockpile

Source: NAPA 2007

Key to this approach is allowing adequate time for aggregate to drain. When storing aggregate on an incline, add new materials at the bottom of the incline and push materials that have had more time to dry further up the incline. Train loader operators to take materials from the top of the incline. Additionally, consider dividing aggregate into two stockpiles, and alternate use of the stockpiles to allow newly received material time to drain.

Training loader operators to take from at least two feet above ground level can substantially reduce moisture content. APAC-Mississippi, Inc, a CRH Company, evaluated moisture content in a 9-foot-high stockpile of coarse sand 24 hours after a 2-inch rainfall. As illustrated in Figure 9, a substantial change in moisture content – from 6 to 18% – was observed at approximately 2 feet above ground level. APAC-Mississippi posts this illustration on loader windows and plant control house windows to remind staff of this practice (Sines 2022). Plant operators will need to apply judgement in cases of fine materials that could compact tightly under loader tires and cause clumping that affects feeder performance.

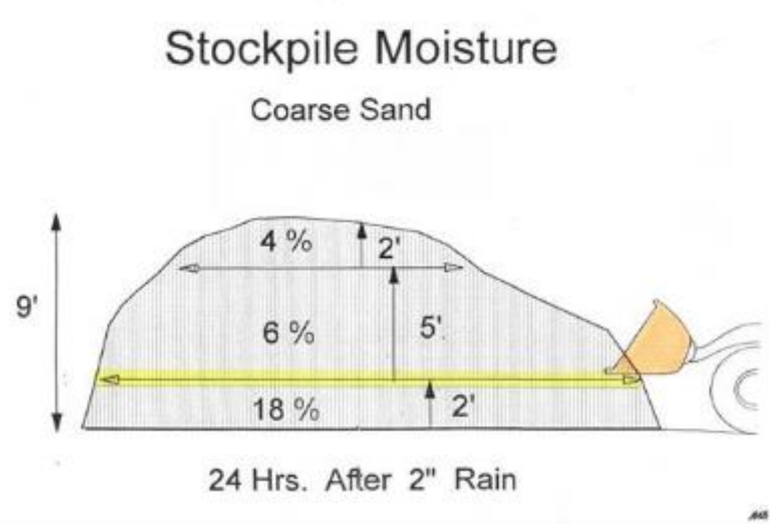

Figure 9. Moisture content in a stockpile

Source: Sines 2022

Case study: Paved stockpile area

Michigan Paving & Materials Co. (a CRH Company) evaluated stockpile moisture content at two similar asphalt mixture plants. Their Grand North and Grand South plants are only 8 miles apart and use the same aggregate. The stockpile area at Grand North was paved at a cost of about $10,000, while the stockpile area at Grand South remained unpaved. In 2020, the aggregate composite moisture at Grand North was measured as 4.6% compared to 5.2% at Grand South, a reduction of nearly 12%. Michigan paving estimated the paved stockpile area avoided more than 14,000 Btu/ton in natural gas consumption, saving over $10,000 each year (NAPA 2022b).

Adjust stockpile height and capacity. Fine and coarse aggregate stockpiles behave differently when exposed to rain. Thissen (2010) observed that river sand loses moisture while RAP gains moisture over time. Increasing the capacity and decreasing the height of the stockpile gives river sand more opportunity to drain; a similar phenomenon would be expected for washed aggregates. The converse would be applied to aggregates that gain moisture over time, such as RAP/RAS and unwashed crushed stone. These measures are reported to have decreased heating costs significantly (Thissen 2010).

Grade the site to eliminate ramps to cold feed bins. With a flat grade between stockpiles and cold feed bins, loaders use less fuel – and reduce wear on the brakes.

Maximize burner efficiency. Choosing the most efficient burner option when designing a new system or retrofitting an existing system is central to limiting energy waste. However, choosing an efficient burner is only one factor. The burner should be sized appropriately to match other plant components including the drum, baghouse, etc. The burner system needs regular maintenance to ensure optimal performance. Burner tuning should be checked monthly or quarterly, and nozzles need to be cleaned often to ensure they atomize fuel effectively; burners using fuels that are less clean than natural gas should be cleaned and tuned more often. A burner's manufacturers should be consulted for instruction on best practices for maintaining optimum performance.

Did you know?

Burner tuning should be checked regularly using a portable combustion analyzer, at least annually or semi-annually. A skilled technician can interpret combustion quality and adjust for desired improvements within the regulatory emission limits (Swanson 2021). Deferred burner maintenance can lead to significantly increased fuel consumption, even to the point of causing a generalized burning smell around the plant (Gunkel 2022).

Insulate drying drum casing. Heat loss from the casing or shell of the drying drum is typically ~5-10%. Insulating the shell reduces energy usage and energy loss. Most new dryer drums are insulated (NAPA 2007), and insulation can be added to uninsulated drums provided care is taken to avoid damaging equipment. Some counter flow continuous mixer designs include a mixing drum built around the drying drum to take advantage of the drying drum heat loss, such as Astec's Double Barrel and CMI Roadbuilding's E3 RAP-Star series.

Reduce exit gas temperature. According to NAPA, equipment manufacturers' modeling shows that a reduction in exit gas temperatures of 40°F can reduce fuel consumption by 4%. High exit temperature indicates less efficient aggregate drying. See *3.4 Dust Collectors* for recommendations on keeping baghouse temperatures only slightly above the dewpoint.

The exit gas temperature is directly related to the use of flights within the dryer. Effective flights enable consistent veiling, whereby the aggregate will be spread evenly as it falls across the drum cross section through the hot gas. The areas with less aggregate veiling will not effectively transfer heat from the gas to the aggregate; thus, the exhaust fans will draw hot gases more easily through those areas, increasing the temperature of the gas as it leaves the drum. Worn flights often cause more material to be dropped on the uplift side, leaving an open area on the down side for the hot gases to pass through. Conversely, most flights will not drop material on the uplift side of the drum when they are too lightly loaded, leaving a passage through which hot gases can escape on the uplift side. The efficiency and productivity losses caused by uneven veiling are exacerbated with mixes with high RAP content and by open graded mixes. Restoring the worn flights, replacing existing flights with modern flight designs, or changing the flight pattern to improve heat transfer and reduce the exit gas temperatures will improve fuel efficiency (NAPA 2007, Swanson 2021).

Spotting uneven veiling

Burned paint on one side of the exhaust gas housing's exterior often indicates excessive heat loss on the downward side of the drum rotation caused by inadequate flighting. Check metal surface temperatures in a horizontal line across the upper area of the dryer intake breeching to identify and address temperature variations.

Photo courtesy of Maxam Equipment.

Reduce material temperature using warm-mix asphalt. In the past, it was common practice to increase the production temperature by 10°F or more above the target design temperature to improve workability and compaction. That temperature increase came at the cost of higher energy use and premature aging of the hot-mix asphalt. Today, warm-mix asphalt offers the same workability and compaction benefits, while consuming considerably less energy. A report by the National Cooperative Highway Research Program found that those plants in their data sample using warm mix while operating at or near the plant's design capacity realized burner fuel savings of 22% by decreasing the mix temperature by an average 48°F. They calculated that approximately 1,100 Btu could be saved per degree Fahrenheit change per ton, although well-insulated plants will see lower fuel savings than uninsulated plants (National Academies 2014).

Warm-mix asphalt reduces the mix temperature by 10 to 100°F while using the same aggregates, asphalt cement, production plants, and jobsite equipment. The difference is that it uses additives to reduce the viscosity of the asphalt cement so that less heat is needed to accomplish that end. There are three kinds of warm-mix technologies: foam, wax, chemical (Braham 2021, MWV 2013).

- Foaming involves adding water into the process, and the instantaneously evaporating water causes the asphalt cement to foam and expand. This can be accomplished by adding dedicated equipment to add the foam or adding synthetic zeolites with water in the crystalline structure.

- Waxes can be added with the aggregate in dry form, or with the binder in wet form.
- Chemicals can be added to the asphalt cement directly to reduce its viscosity.

The benefits of warm-mix asphalt's lower production temperatures include:

- Reducing energy use by up to 55% (MWV 2013), and emissions by up to 50% (Braham 2021). Actual energy and emission reductions vary as a function of actual temperature reductions achieved, equipment configuration, site-specific conditions, and chemical compound.
- Offering longer haul distances since a lower starting temperature will not lose heat as quickly during transport (MWV 2013).
- Offering an extended paving season since the asphalt mixture remains workable at lower temperatures (MWV 2013).
- Improving compaction, which makes the pavement surface more resistant to water infiltration (MWV 2013).

Many asphalt mixture producers today have adopted the warm-mix technologies to gain its non-energy benefits, though some still produce at hot-mix temperatures (Braham 2021, MWV 2013). NAPA's survey on warm-mix asphalt use indicates a little less than 50% of mix produced using warm-mix technologies is at reduced temperature (NAPA 2020).

Use alternative fuels. Most dryer drum burners have the capacity to burn liquid and gaseous fuels, and switch among them as needed. When natural gas prices are competitive, most plants that have access to natural gas will use it. Plants that are not located near natural gas lines may instead turn to fuel oils, recycled oils, propane, LNG, or CNG depending on costs and availability.

Recycled oils cost about half the market price of No. 2 fuel oil, have higher energy content than diesel, and burn cleanly, making them viable options (NAPA 2007). Because they are reclaimed, they require additional filtering to protect the burner from impurities; without careful procurement and filtering, entrained metals, sulfur compounds, bound nitrogen, and halogens can cause problems with the fuel line and burner, including corrosion and increased emissions. Their higher viscosity also necessitates an in-line heater to raise them to ~120-160°F; adequate preheating to achieve the lower fuel viscosity required for a particular burner determines whether the recycled oil can be burned cleanly and efficiently.

Did you know?

NAPA recommends painting recycled oil tanks a dark color to effectively absorb solar radiation, thus reducing the amount of supplemental in-line heating required. (NAPA 2023)

Consider alternative equipment. Several manufacturers are now marketing fully electric drive wheel loaders and other construction equipment. Electric drive loaders offer reduced emissions, noise, and maintenance costs.

Optimize production. Stops and re-starts may use considerably more energy. Reducing these by optimizing the production schedule could save energy. In one case study in The Netherlands, an asphalt plant reduced the number of restarts by 50% through better scheduling and planning, resulting in energy savings of 1.5% (Roseboom 2017). NAPA members also have access to the publication Balancing Production Rates in Hot Mix Asphalt Operations to help find optimization strategies (NAPA 1996).

4.2 Asphalt Cement and Heating

Most asphalt mixture plants rely on hot-oil heaters for heating asphalt cement in storage tanks, transfer lines, pumps and valves, as well as maintaining the temperature of asphalt mix in storage silos. Specific measures for increasing efficiency in these components follow.

Hot-Oil Heaters. The hot-oil heater uses electricity or fuel combustion to transfer heat to oil, which in turn circulates through the plant equipment that requires supplemental heating. Options for improving the efficiency of hot-oil heaters include:

- Select the most efficient hot-oil heater. Good heater designs typically reach 85% efficiency and maximize exposure of the hot-oil heat transfer coils to the heat source. Most heaters have a useful life of 20-30 years, so in the absence of early replacement, most heaters currently in service may not match the efficiencies of the best heaters now offered on the market. Other measures to improve efficiency will be more tenable between capital replacement cycles.

- High exit gas temperatures from the stacks of existing fuel-fired heater systems indicate an inefficient heater. When heater replacement or rebuilding are not viable, consider adding a heat exchanger to the exhaust stack to capture the waste heat and use it to preheat the heat transfer oil. Manufacturers of these heat exchangers report efficiency gains of 3 to 9%.

- When replacing a hot-oil heater, consider a high-efficiency electric heater. Modern electric heaters can offer reduced operating costs and maintenance, extended heater life, and emissions reductions (PHC 2023). As the share of renewable generating sources in the electric power mix increases, using electric heaters will help the industry reduce its carbon footprint.

Piping Insulation. Once heated, the hot oil is circulated throughout the plant to applicable plant equipment via dedicated piping. Similarly, liquid asphalt binder also is moved from the storage tank to the mixer via piping. Inadequately insulated piping transfers heat to the surrounding air instead of to necessary end uses. All pipes, elbows, valves, pumps, etc., should be properly insulated to avoid this energy waste. Insulation is inexpensive, and payback periods are very short, especially when energy costs are high. Pre-formed insulation is widely available for most piping sizes and shapes, and heat jackets are available for specialized application. NAPA 2023, pages 19-23 and Appendix D, offers an easy approach for estimating energy saving from proper pipe insulation. Use thermal imaging camera technology to help identify inadequate or compromised insulation.

Insulate asphalt lines

Astec, a manufacturer of asphalt storage tanks and heaters, claims that adding one inch of insulation to 100 feet of a 4-inch asphalt pipe could save over 21,000 gallons of No. 2 fuel oil per year (Astec 2023).

Tank and Silo Insulation. Most modern asphalt storage tanks have a standard of 6 inches of built-in insulation. Older tanks often have less insulation, and some vertical storage tank manufacturers choose to not insulate the bottoms of their tanks at all, leaving room for improvement at many plants. According to NAPA modeling, a 30,000-gallon horizontal asphalt tank with 6 inches of insulation will require 25,660 Btu per hour to maintain heat. That same tank with only 3 inches of insulation would consume 83% more energy, and a tank with no insulation would consume 5600% more energy. Asphalt mixture storage silos also should be well insulated. Best-in-class silos have up to 12 inches of insulation on the top and around the cone, and 6 inches along the wall (NAPA 2007). For all applications, any exterior insulation should be inspected regularly for damage or water infiltration and replaced as needed. Use thermal imaging camera technology to help identify inadequate or compromised insulation.

Insulate tanks and silos

Evaluate all tanks and silos for opportunities to improve insulation. Inspect any exterior insulation regularly for damage or water infiltration and replace as needed.

4.3 Reclaimed Asphalt Pavement

When RAP is used, it is mixed with the hot aggregate in the mixing stage. Heat transfers from the hot aggregate to the RAP, allowing the RAP to soften and be integrated into the asphalt mixture. According to NAPA, average RAP content of a mix in the US is just over 20%, but this varies by state, with some states exceeding average RAP content of 30% (NAPA 2020). New plant technologies enable production of mixes with RAP content of over 50%, with rare examples of mixes reaching 100% RAP.[3] Another challenge is ensuring mix quality, which is addressed by using softer virgin binder grades or recycling agents when the RAP quantity exceeds 15-20%.[4]

The energy savings from using RAP are primarily attributable to the product life cycle, as recycling the asphalt pavement means that lower quantities of virgin aggregates need to be quarried, and less asphalt cement needs to be produced and heated. Using RAP does not cause an appreciable effect on energy use at the plant itself (Frederick 2009). Challenges associated with using RAP include the additional moisture that the RAP introduces during the mixing stage, and the additional processing steps needed to make the RAP ready for introduction into the mixing stage.

Efficient veiling and heat-transfer efficiency in mixes with high-RAP quantities can present a challenge. Until recently, the energy savings of using RAP were largely offset by high stack heat losses at the asphalt plant. With improved dryer flight designs and variable frequency drum drives, the stack temperature can be managed to virtually eliminate the additional stack heat loss (Swanson 2021).

4.4 Truck Operation and Fleet Management

Transporting asphalt mixture to the job site imposes a significant cost to the industry. Improving truck operation and fleet management reduces delivery time and fuel consumption.

Track fuel consumption. Fuel consumption can be simply determined by gathering information on the miles and hours a truck was driven and the time spent idling. Installing diesel flow meters in trucks provides more precise

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[3] Examples of mixing drums from major plant manufacturers that accommodate mixes with 50%+ RAP can be reviewed at: https://www.astecinc.com/products/drying-mixing/double-barrel-xhr-dryer-drum-mixer.html; https://www.ammann.com/en/news-media/news/modern-asphalt-production-uses-reclaimed-asphalt-2; https://www.gencor.com/equipment/drum-mix-plants/; https://www.cmi-roadbuilding.com/asphalt/e3.

[4] For further guidance on using recycling agents for high RAP mixes, NAPA published the *Practical Guide for Using Recycling Agents in Asphalt Mixtures* in 2020.

information on real-time fuel consumption (or later in downloadable format). Flow meters help track truck efficiency and identify further improvement options, such as retrofitting or replacement.

Reduce idle time. The American Trucking Association (ATA) reports that idling consumes 1.2 billion gallons of truck diesel fuel annually (ATA 2008). Reducing idling time could save fuel and maintenance costs.

For example, Titan America, a ready-mixed concrete producer, collaborated with truck drivers to identify and promote a number of best practices, including shutting off the engine between loads; improving dispatching; automating ticketing, tarping, and release agent spraying; and wiring radios to the battery to avoid needing the engine on to power the radio. The result was a 38% reduction in idle time within 2 months (Downs 2009). Please also see the accompanying case study from Superior Paving Corp.

Case study: Route optimization and reduce idle time

Superior Paving Corp., a paving and asphalt mix supplier in Virginia, uses a GPS-enabled trucking logistics software system to track load cycle analysis, monitor equipment utilization, and optimize their trucking operations. The system provides real-time information, allowing them to make adjustments during the day to respond to changing conditions at the jobsite. They require independent truckers to install the GPS units as well, providing the fleet manager with a holistic view of trucking operations.

Superior uses the logistics system to track odometer readings for individual trucks, feeding the data into their equipment management software for preventive maintenance scheduling. They also use the system to track engine idling and support the company’s 5-minute idling policy. They have established an idling incentive program to motivate drivers to reduce their idling time. Each category of equipment is assigned a target idling percentage. Drivers earn a $50 gift card each month they achieve their idling target. In the first 8 months of the incentive program, 42% of drivers met their target and earned the incentive (Mitchell 2022).

Route optimization. A route-planning system such as GPS (global positioning system) can save fuel by finding a shorter distance to the construction site. Road gradation, idling time, and other factors influencing fuel consumption should be considered.

Optimize capacity. Load a company’s own trucks to their gross weight rating to minimize the number of truck loads to individual job sites. Customer trucks should still be loaded based on net weight to align with ordered product (NAPA 2008).

Back-hauling RAP. On milling projects, use the same trucks that deliver asphalt mix to the job site to back-haul RAP to the plant. This may require use of a release agent at the job site (NAPA 2008).

Engine block heaters. When cold weather necessitates engine block heaters, put the heaters on timers. This saves energy, saves start-up time in the morning, and reduces wear on trucks (NAPA 2008).

4.5 Miscellaneous

Alternative Binder Extenders. Producers may investigate alternative binder extenders such as lignin. Lignin is an organic polymer comprised of the cell walls of plants. It is derived during several industrial processes, including as a by-product of chemical pulping in the paper industry. A relatively new innovation involves adding lignin into the asphalt mixture as a binder, partially replacing asphalt cement (van Vliet 2016). Beyond extending the binder with the bio-based product, lignin also acts as an antioxidant, slowing the oxidation responsible for aging asphalt pavement (Williams 2008). Adding lignin requires little to no additional processing, lowers binder heating temperature,[5] and reduces the pollutant emissions associated with asphalt (van Vliet 2016, Wageningen 2020). Because the petrochemical industry is becoming better able to break down petroleum into higher value products, finding extenders for asphalt binder will become increasingly important as bitumen becomes scarcer.

5 Summary

By increasing energy efficiency, companies can cut costs and increase predictable earnings even when faced with ongoing energy price volatility. Considering the negative impacts that such volatility has on the bottom line, such as potential sharp increases in natural gas prices, energy efficiency improvements are needed today more than ever, and many firms are reaping the rewards of these investments. Companies also turn to energy-efficient methods to reduce their criteria pollutant and carbon emissions, to meet corporate environmental goals.

This *Quick Guide* summarizes many energy-efficient technologies and practices that are proven, cost-effective, and available to implement today. To achieve ongoing success, establish a focused, strategic energy management program that helps you identify and implement energy efficiency measures and practices across the organization and ensure continuous improvement. Research the economics and applicability of the energy efficiency measures presented in this guide, and assess each one's feasibility and potential benefits for your facility.

[5] The CHAPLIN project in the Netherlands analyzes the effects of adding lignin as a binder to asphalt. The project found that lignin reduces the processing temperature from 170C to 130C, resulting in about 20% energy savings. At time of this writing, a journal article on its findings has been submitted for publication, but not yet published. Details about the project are available from the press release (in Dutch): Bio-asfalt op basis van lignine krijgt flinke zet in de rug - WUR.

6 Glossary

ANSI	American National Standards Institute ASD adjustable speed drive
ATA	American Trucking Association
Btu	British thermal unit
CO	carbon monoxide
DOE	Department of Energy
EASA	Electrical Apparatus Service Association EPA Environmental Protection Agency
GHG	greenhouse gas
GJ	gigajoule
GPS	global positioning system
HID	high-intensity discharge
HMA	hot-mix asphalt
hp	horsepower
HVAC	heating, ventilation, and air conditioning
IAC	Industrial Assessment Center
kBtu	thousand British Thermal Unit
kg	kilogram
kW	kiloWatt
kWh	kiloWatt-hour
lb	pound
LED	light emitting diode
MMBtu	Million British thermal units
m	Meter
m^3	cubic meters
MJ	Megajoule
NAPA	National Asphalt Pavement Association
NEMA	National Electrical Manufacturers Association NO_X nitrogen oxide
pH	Potential of Hydrogen
psi	pounds per square inch
psig	pounds per square inch gauge
VFD	variable frequency drive

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Treasure Map FOR ASPHALT MIXTURE PRODUCTION PLANTS

ENERGY STAR

Grab a clipboard and take this map along on your treasure hunt. Focus on uncovering opportunities to save. When you find something, make notes about location; tools, materials, or expertise needed; or further research required. Feel free to add to or modify this list to suit your own needs. For more treasure hunt resources, visit www.energystar.gov/treasurehunt.

Facility Name ______________________ Date __________ Team ______________________

1 Facility Management

- ❑ Review the plant's energy tracking system, billing records, or other sources of consumption data. Identify any spikes or unusual changes in energy use over the past year.
- ❑ Check the facility's energy action plan and reports from energy audits, assessments, and treasure hunts (if available) to see if earlier identified energy savings measures have been implemented.
- ❑ Inspect maintenance plans and records to identify areas to review during the treasure hunt. Routine or preventative maintenance on neglected equipment may yield energy savings.
- ❑ Review building management system (BMS) and/or building automation system (BAS) code, if applicable, to ensure that specific commands to reduce unneeded energy consumption (e.g., on/off times) remain active.
- ❑ Consider facility maintenance during daylight hours to reduce the need for lighting and HVAC during unoccupied periods.
- ❑ Consider using software and control systems that provide real-time monitoring, including integration with real-time fuel sensors.
- ❑ Check that the facility has a comprehensive training program with energy management emphasis for plant operations personnel, and that all staff have been trained and receive periodic refresher training. For example, see sections 2.2 and 4.1 of the Energy Efficiency and Cost Saving Opportunities for Asphalt Mixture Production guide.

2 Dust Collectors

- ❑ Verify proper dust collector maintenance schedules are being followed, including:
  - ❑ Identify leaks. Track identified leaks to ensure they are sealed. Replace dust seals regularly, and inspect hidden areas around augurs and chutes.
  - ❑ Inspect pulse air jets. If automated to be controlled by differential pressure, confirm correct operation.

NOTES:

- ❑ Inspect mechanical shakers.
- ❑ Inspect bags.
- ❑ Inspect cartridges.

- ❑ Optimize exhaust gas temperature to keep temperature closer to the dewpoint.
  - ❑ Consider real-time moisture sensors to determine the current dewpoint and adjust operations to align more closely.
  - ❑ Consider automating drum speed to maintain the target exhaust gas temperature for the baghouse.
  - ❑ Consider using a small, secondary burner to reheat exhaust gas before it enters the baghouse if temperature falls too close or below dewpoint.
- ❑ Assess, or consider employing, a minimum effective draft by using dampers and/or variable-speed fans to control the draft.
- ❑ Consider replacing manual dust collectors with automated dust collectors.
- ❑ Check fans. Resize and/or slow down fans (e.g., with variable frequency drives (VFD)) that are too big.
- ❑ Check the differential pressure across the dust collector (pressure difference between the dirty and clean side of the bags). Maintain pressure between 4 and 5 inches of water.
- ❑ Consider using a differential pressure control system on the cleaning system.
- ❑ If using a compressed air jet-pulse cleaning system, check that the system is using the minimum effective pressure (usually 60-70 psi).
- ❑ Consider using a short pulse to shake extra dust off in the case of compressed air blowdown systems.
- ❑ Inspect for hot spots on duct work and exhaust fans using an infrared camera on a yearly basis.
- ❑ Inspect system insulation in duct work and baghouse. Repair or replace damaged insulation, or add insulation where current insulation is inadequate.

3 Aggregate Handling, Drying and Heating

- ❑ Check that aggregates are under shelter to avoid moisture increases.
- ❑ Check that stockpiles have adequate drainage. Consider creating paved and sloped areas for stockpiles. Check that loader operators take aggregates from higher in piles when loading aggregate bins.

NOTES:

- ❑ Consider grading site to eliminate inclines to the cold feed bins to reduce fuel consumption and loader wear.
- ❑ Evaluate burner efficiency. Check that burners are tuned at least once per year, and more often if they use less clean fuels. Check that regular maintenance (e.g., burner cleaning) is performed and documented. Consider VFD for drum. Ensure operators are trained on operating efficiently.
- ❑ Consider checking burner using a gas analyzer and document the oxygen and carbon monoxide percentages (O% and CO%) and NOx (ppm).
- ❑ Inspect drying drum casing insulation. Repair or replace damaged insulation or add insulation where current insulation is inadequate. Use thermal imaging camera technology to evaluate.
- ❑ Inspect air dampers on inlet and outlet ends of drum, and on RAP inlet.
- ❑ Evaluate opportunities to optimize drying drum exit temperature.
  - ❑ Evaluate condition of flights, and replace worn flights if inefficient veiling is causing high exit gas temperatures.
  - ❑ Evaluate the flight configuration for the types of mixes and range of RAP content.
- ❑ Consider options for reducing material temperature using warm-mix asphalt.
- ❑ Consider alternative equipment, especially electric equipment (e.g., electric drive wheel loader)
- ❑ Consider opportunities for optimizing production, especially by reducing stops and re-starts that can use more energy. Ensure operators are trained in maximizing production efficiency.

4 Asphalt Cement and Heating

- ❑ Inspect hot-oil heaters. Check that burners are tuned at least once per year, and operators are trained on operating efficiently.
  - ❑ Check stack exit gas temperatures for fuel-fired heaters. If temperatures are high, consider replacing or rebuilding the heater, or adding a heat exchanger to the exhaust stack to capture waste heat and use it to preheat the heat transfer oil.
  - ❑ Consider checking burner using a gas analyzer and document the oxygen and carbon monoxide percentages (O% and CO%) and NOx (ppm).
  - ❑ Replace heaters with high-efficiency electric heaters.

NOTES:

- ❑ Inspect piping insulation for any gaps or damage. Consider insulation on all system elements (e.g., jumper lines, valves, and manholes). Repair or replace damaged insulation or add insulation where current insulation is inadequate. Use thermal imaging camera technology to evaluate.
- ❑ Inspect tank and silo insulation for any gaps, damage, or water infiltration. Repair or replace damaged insulation or add insulation where current insulation is inadequate. Use thermal imaging camera technology to evaluate.
- ❑ Evaluate opportunities to add lignin to asphalt.

5 Reclaimed Asphalt Pavement/ Recycled Asphalt Shingles

- ❑ Check that flighting is configured to optimize veiling efficiency given the typical range of RAP content the plant produces.
  - ❑ Verify processes are established to pre-inspect every incoming load of RAP at the production plant and stockpile for contaminants.
  - ❑ Consider options for stockpiling broken RAP separately from milled RAP.
  - ❑ Evaluate opportunities for covering RAP stockpiles.

6 Truck Operation and Fleet Management

- ❑ Coordinate trucking and the scheduling of third-party orders so that production at the plant is balanced with demand. Optimizing production saves energy by reducing stops and re-starts.
- ❑ Back-hauling RAP. On milling projects, ensure the same trucks that deliver asphalt mix to the job site are used to back-haul RAP to the plant.
- ❑ Analyze fuel consumption. Verify that information on miles and hours driven, and time spent idling (including loading and traveling off- road) are tracked and analyzed to optimize fuel efficiency.
- ❑ Inspect, or consider installing, diesel flow meters in trucks to provide more precise information on real-time fuel consumption.
- ❑ Identify opportunities to reduce idling time, including:
  - ❑ Shutting off the engine between loads.
  - ❑ Training fleet coordinators on improving truck dispatching.

NOTES:

    - [ ] Identifying technologies that reduce idling time, such as automatic release agent spraying system, automatic tarping, and automatic ticket writers.
    - [ ] Wiring radios to the battery to avoid needing the engine on to power the radio.
- [ ] Evaluate current routes. Consider a route-planning system (such as GPS) to save fuel by finding shorter distances to desired locations.
- [ ] Optimize capacity. Ensure a company's own trucks are loaded to their gross weight rating to minimize the number of truck loads to individual job sites.
- [ ] Engine block heaters. When cold weather necessitates engine block heaters, ensure the heaters are on timers.

7 Compressed Air

- [ ] Evaluate proximity of compressor to factors that may impact its operational efficiency (e.g., excess dust, heat from a nearby source), and consider relocating compressor if necessary.
- [ ] Verify proper maintenance schedules are being followed, including:
    - [ ] Check filters are cleaned or replaced.
    - [ ] Check O-rings.
    - [ ] Check motors and compressors are properly lubricated.
    - [ ] Inspect fans and pumps where applicable.
    - [ ] Inspect drain traps periodically to ensure they are clean and not stuck in the open or closed position.
    - [ ] Inspect belts, where applicable.
    - [ ] Specify pressure regulators that close when failing.
- [ ] Review compressed air applications for excessive pressure, duration, or volume.
- [ ] Inspect, or consider installing, ultrasonic acoustic detector to identify leaks and the high-frequency hissing sounds associated with air leaks.
    - [ ] Track identified leaks to ensure they are repaired. Develop a leak program to assure leak detection and correction are ongoing.
- [ ] Confirm air is completely turned off to equipment no longer active (at solenoid valve).

NOTES:

- ❑ Assess, or consider implementing, a control strategy to ensure that only the right amount of compressed air, at the right time, is generated and used in the production system.
    - ❑ To determine proper control systems, assess compressed air requirements over time to establish a load profile.
- ❑ Evaluate if air pressure can be reduced to the lowest practical set point. Every 2-3 psi decrease in system pressure can reduce energy use of the compressors by 1%.
- ❑ Assess if pneumatic controls or tools can be replaced with electric systems.
- ❑ Identify opportunities for heat recovery of wasted heat from the compressors.
- ❑ Identify opportunities to replace compressors with a variable speed drive (VSD) compressor.
- ❑ Evaluate compressor load profiles to reduce partially loaded compressors. Verify compressor controls are sequenced properly to avoid frequent loading/unloading.
- ❑ Evaluate the potential to reduce header pressure during non-production time.
- ❑ Evaluate overall preventive and predictive maintenance of system.
- ❑ Confirm overall control system operations.

8 Motors

- ❑ Locate and identify all motors. Inventory conditions and specifications of each motor.
- ❑ Assess motor needs against actual use to determine if properly sized to meet the needs of its driven equipment. Replace wrong-sized motors with correct size and high-efficiency motors.
- ❑ Consider maintenance, repairs and upgrades to the motor systems, including economic costs and benefits using life-cycle costs.
    - ❑ If upgrades are pursued, monitor the upgraded system's performance to determine actual cost savings.
    - ❑ Consider purchasing energy-efficient motors in order to reduce the motor's life-cycle costs.
    - ❑ Consider replacing smaller motors with NEMA Premium® efficiency motors.

NOTES:

- ❑ Evaluate overall preventive and predictive maintenance of system.
- ❑ Confirm overall control system operations.
- ❑ Check shutdown practices for motors that are not in use to prevent idling. Consider automatic shutdown of motors.
- ❑ Consider adjustable-speed drives (ASDs) and VFDs based on use pattern of motors.
- ❑ Consider replacing generators and diesel engines on crushing equipment with motors.
- ❑ Inspect electrical cabinets and high output large bearings with infrared cameras and record findings yearly.

9 Lighting

- ❑ Identify where lights have been left on in unoccupied spaces (e.g., common areas, storage rooms, restrooms, break rooms, outdoor areas).
- ❑ Identify and assess opportunities to use automated lighting controls:
    - ❑ Occupancy/motion sensors for low-traffic areas.
    - ❑ Timers or daylight sensors to dim or turn off exterior lights during the day.
    - ❑ Dimming controls in locations where there is natural lighting (e.g., near windows).
- ❑ Confirm that installed lighting controls are operating as intended.
- ❑ Assess need to institute a regular cleaning plan for lamps/fixtures for maximum light output.
- ❑ Identify where reflectors can be practically added to existing lighting.
- ❑ Assess whether any areas are over-lit, compared to requirements or design levels; consider opportunities for de-lamping.
- ❑ Identify and de-energize and/or remove fixtures and ballasts that are not in use.
- ❑ Evaluate the opportunity to upgrade to more energy-efficient lighting options:
    - ❑ Replace all lights with LEDs.
    - ❑ Use LED Exit signs in place of incandescent or CFL models.

NOTES:

10 Building Envelope

Note: Some elements of this section may be relevant only to larger plants with attached office space. Please use judgement in determining which are applicable.

- ❑ Inspect doors and windows to identify gaps or cracks that can be repaired.
  - ❑ Note damaged or missing weather stripping.
- ❑ Note air leaks that should be sealed with caulking or other sealant.
- ❑ Inspect insulation and weatherstripping levels and identify inadequacies to be addressed (including loading docks and garage doors).
- ❑ Assess opportunity to install vinyl curtains in loading areas, if applicable.
- ❑ Note any doors left open to the outside and to any unheated or uncooled areas.
- ❑ Assess the opportunity to install solar film or other window coverings on east, west, or south exposures to reduce solar heat gain and heat loss.
- ❑ Assess the opportunity to install air lock doors for main entrances, if applicable.
- ❑ Assess the opportunity to install a reflective ("cool") roof covering in warm climates.
- ❑ Assess the opportunity to use natural vegetation to moderate solar and wind impact.

11 Plug Loads

Note: Some elements of this section may be relevant only to larger plants with attached office space. Please use judgement in determining which are applicable.

- ❑ Identify any new office equipment that will be needed soon; make plan to ensure they are ENERGY STAR certified where possible. (www.energystar.gov)
- ❑ Identify any equipment left on overnight (including those left in sleep/ idle or screen saver mode).
- ❑ Ensure that power management settings are activated on office equipment such as computers, monitors, printers, and copiers.

NOTES:

- ❑ Ensure that any large-screen TV monitors are turned off during unoccupied times.
- ❑ Use networked printers, rather than personal printers in offices or workstations.
- ❑ Identify and discontinue the use of personal heaters and fans in offices or workstations (the use of such personal devices may indicate broader hot/cold issues that should be addressed at the system level).
- ❑ Identify where power strips can be used for easy disconnect from power source. Consider the use of advanced power strips.
- ❑ Assess plan for educating staff to unplug rechargeable devices once charged.
- ❑ Check if vending machines get turned off or put in sleep mode at the end of the day.
- ❑ Consider installing motion/occupancy-based vending machine controls.
- ❑ Look for opportunities to replace older vending machines with new ENERGY STAR certified vending machines.

12 HVAC

Note: Some elements of this section may be relevant only to larger plants with attached office space. Please use judgement in determining which are applicable.

- ❑ Identify and make plans to address instances of simultaneous heating and cooling.
- ❑ Ensure that thermostats and outside air temperature sensors are properly calibrated/maintained.
- ❑ Ensure that thermostats are set to appropriate temperatures based on season and local weather conditions.
- ❑ Confirm proper implementation of a temperature setback policy for heating/cooling when the building is unoccupied (including any special considerations for summer months).
- ❑ Perform testing and balancing of air and water systems.
- ❑ Ensure that thermostats are properly located to be representative of the room or zone for which the temperature is being controlled.
- ❑ Ensure that electronics are located away from thermostats.
- ❑ Ensure that space heaters are not being used in offices, break rooms, and other spaces.

NOTES:

- ❑ Identify where locking covers for thermostats and ventilation controls can be installed to prevent unauthorized adjustments.
- ❑ Ensure free airflow to and from registers.
- ❑ Ensure window shades are available to block excess heat gain; make plan to educate staff about when to use them.
- ❑ Identify where ceiling fans can be installed to move and de-stratify air layers. Ensure all existing ceiling fans are operating properly.
- ❑ Monitor make-up air ventilation; ensure the proper functioning of dampers to achieve outside air requirements.
- ❑ Ensure that HVAC system components are being maintained regularly, including:
  - ❑ Replace filters on a regular schedule.
  - ❑ Inspect and clean evaporator and condenser coils.
  - ❑ Clean fan blades and adjust belts as needed.
  - ❑ Inspect water/steam pipes and ducts for leaks and/or inadequate insulation; address as needed.
  - ❑ Verify and calibrate operation of variable air volume (VAV) boxes, where applicable.
  - ❑ Evaluate furnace/boiler efficiency and clean/tune up as needed (including boiler water treatment and inspection of steam traps, as appropriate).
  - ❑ Check chiller and cooling tower components for fouling or corrosion; ensure proper water treatment is in place.
  - ❑ Check for unusual noise, vibration and/or decrease in performance of compressors/motors.
- ❑ Evaluate how chillers operate during the cold months and determine if chiller or pumps can be shut off.
- ❑ Identify and assess opportunities for installing VFDs for fan and pump motors, and VAV boxes in the ductwork – especially where variable loads are being served.
- ❑ Identify and assess opportunities for demand-controlled ventilation in areas with variable loads (e.g., meeting room, break room).
- ❑ Identify and assess opportunities to use occupancy sensors to control HVAC in offices or meeting rooms.
- ❑ Verify proper preventive and predictive maintenance schedules are being followed. Ensure all components are optimized.
- ❑ Determine whether economizer modes are being used.
- ❑ Confirm non-production modes are used, and schedules are being followed.

NOTES:

ADDITIONAL NOTES: