Shift Work and Potential Health Effects

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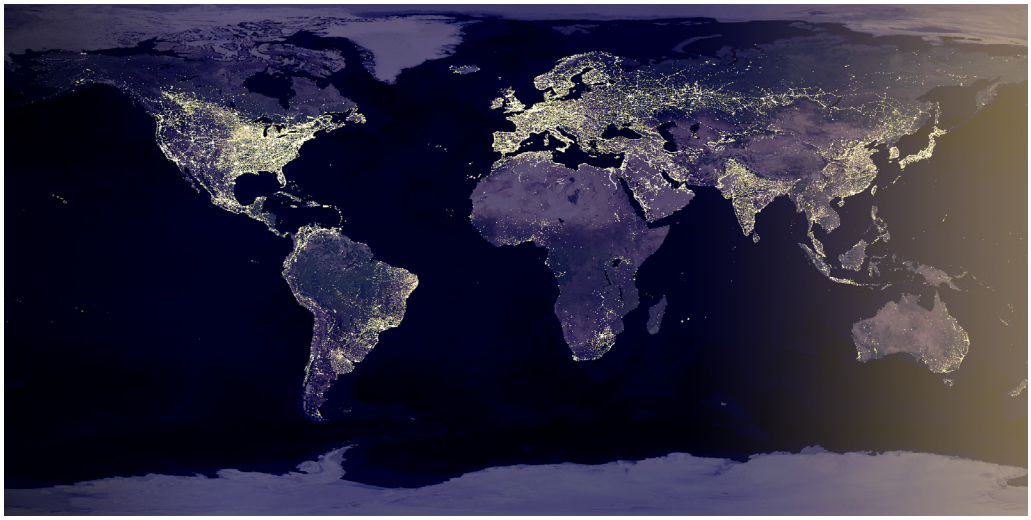
Executive Summary

The objective of this report is to inform the electric power industry of current scientific knowledge on worker health and safety risks associated with shift work in order to support future research planning. Shift work has been found to be associated with increased cancer risks—primarily of breast cancer and (to a lesser extent) prostate and colon cancer. Risk of occupational injuries increases with several common characteristics of shift work—particularly rotating shifts and longer shift lengths. Disruption of circadian rhythms appears to be a major pathway for negative health effects. These disruptions interact with other related biological pathways—including stress, metabolism, and sleep disruption. Limited evidence suggests an elevated risk of adverse reproductive outcomes—including preterm delivery, spontaneous abortion, and low birth weight. Evidence for a causal link between shift work and cardiovascular disease remains inconsistent. Given current scientific uncertainties, it appears prudent to understand and apply insights from the available scientific research to monitor and improve work conditions. Future research will require consistent, detailed characterizations of "shift work" to improve exposure estimates and enhance study comparability, risk characterization, and intervention protocols.

Introduction

Occupational health concerns surrounding shift work have existed for decades (Costa 2003). However, the health issues potentially related to shift work have continued to evolve—moving from short-term or immediate effects (sleep disruption, gastrointestinal disorders, mental distress) to longer-term effects (stress, problems affecting psychological health and social well-being, injuries), including chronic dis-



Why Understanding the Adverse Effects of Shift Work Is Important for the Electric Power Industry

- The International Agency for Research on Cancer (IARC) recently classified shift work as a "probable" human carcinogen.
- The European Union (EU) and other countries have increased regulatory oversight of shift work (via work-time guidelines or directives) based on the opinion that long or irregular work schedules are a health hazard.
- Recent European judicial rulings have financially compensated workers for breast cancer diagnoses on the basis of "occupational causation" due to night-shift work.
- A substantial proportion of workers are engaged in shift work (15–20% in North America and Europe); in the U.S. electric utility sector, this proportion is > 20%.
- There is potential to determine the underlying causes of adverse health effects related to shift work and to develop intervention strategies to protect worker health.
- Recent data indicate that several biomarkers related to circadian ryhthms, stress, and Vitamin D metabolism may aid in understanding underlying biological mechanisms, determining individual susceptibility, and designing risk-prevention programs.

Table 1. Adverse Health Outcomes Associated with Shift Work in Epidemiological Studies

Acute / Subacute Conditions	**Chronic Conditions**
Reproductive outcomes	**Cancer**
Preterm delivery	Breast
Low birth weight	Prostate
Small for gestational age	Colon
Spontaneous abortion	Endometrial
Gastrointestinal disorders	Non-Hodgkin's lymphoma
Peptic ulcers	**Cardiovascular disease**
G.I. distress (e.g., reflux)	Ischemic heart disease
Mental health	Stroke
Depression, anxiety	Hypertension
Sleep disruption	**Diabetes, metabolic disorders**

ease (cancer, cardiovascular disease, diabetes) and reproductive issues (adverse fetal growth, spontaneous abortion) (IWH/OCRC 2010). Human studies reporting associations between shift work and negative health effects have generally reported relatively low risk increases for that proportion of workers in the population (20% or more) who are "exposed" to these types of work schedules. Nevertheless, there is evidence that shift work itself may pose a measureable and potentially preventable risk as an occupational health concern (IARC 2010; IWH/OCRC 2010).

What is "Shift Work"?

Shift work is the outcome of a work-organizing process that requires scheduling worker groups across successive time periods to allow complete coverage of a 24-hour day. The specific grouping and timing of work periods required to cover a round-the-clock schedule may take a broad range of forms—with "shift work" generally referring to any work schedule that does not match that of the traditional "business day" (9 a.m. to 5 p.m.). The basic characteristics of shift work may include the following (Stevens et al. 2011; BLS 2005):

- Permanent night shift (late start after 11 p.m.); afternoon/evening, or "swing," shift (late afternoon or early evening start after 2 p.m.); morning shift (early start prior to 6 a.m.)
- Day versus non-day shift (portion of work post-midnight)
- Rotating shift (requiring periodic changes between morning, evening, and/or night shifts)
- Rotating shift directions, which are either forward/clockwise (day to evening to night) or backward/counter clockwise (evening to morning to night)
- Continuous (7 days per week) or discontinous (weekend or mid-week breaks) shifts, which can be rotating or permanent
- Rotating shift rates, which can be daily, every 2–4 days, weekly, or monthly
- Long shift lengths (> 8 hours)

- Split shifts (2 or more distinct work shifts in a 24-hour period)
- On-call shifts (having no pre-arranged schedule)

Labor surveys in North America and Europe have reported a high, and sometimes, increasing prevalence for shift work across a range of industrial sectors.

Labor surveys in North America and Europe have reported a high (and sometimes increasing) prevalence of shift work across a range of industrial sectors (BLS 2005; McMenamin 2007; Costa et al. 2004; Wong et al 2011). Multiple factors, ranging from industry production demands to worker preferences, influence the degree to which individuals engage in shift work. However, in order to clarify postulated causal links between shift work and disease or injury, contributions from industry-specific factors and individual worker characteristics need to be taken into consideration—both to describe "exposure" and to estimate any related risks.

Shift Work–Related Potential Health Effects

Epidemiological studies have reported a range of adverse health effects associated with some form of shift work, including diseases of the gastrointestinal tract (Knutsson and Boggild 2010), the cardiovascular system (Frost et al. 2009; Puttonen et al. 2010), the endocrine system or metabolism (Lowden et al. 2010; Suwazono et al. 2006), the reproductive system (Bonzini et al. 2011), mental health problems (Haines et al. 2008; Bara and Arber 2009), and cancer (Costa et al. 2010; IARC 2010). (See Table 1 for a summary.) In particular, the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) has classified shift work as a probable human carcinogen (see Table 2). This classification has focused interest on cancer risk, which will be detailed below (Straif et al. 2007; IARC 2010). The occurrence of breast cancer, which was measured in fewer than 10 studies, was considered the primary cancer type for the assessment. However, the IARC review raised several questions about the epidemiological database, which included studies based on data from single occupations (such as health care or transportation); limited adjustments for confounders or concurrent risk factors (for example, other occupational exposures); detection bias; and inconsistent definitions of "shift work" (Costa et al. 2010; IARC 2010; Fritschi et al. 2011). Recently, members of the IARC Working Group published recommendations for future human studies that evaluate shift work, including detailed advice regarding exposure parameters to enhance study comparability (Stevens et al. 2011). Table 3 summarizes the recommended exposure parameters.

Breast Cancer Risk

To date, fewer than 10 primary studies have served as the basis for assessing the association between shift work and breast cancer.

To date, fewer than 10 primary studies have served as the basis for assessing the association between shift

Table 2. International Agency for Research on Cancer (IARC): Summary Findings on Shift Work

IARC Evaluation of Carcinogenicity*
Cancer in Humans
Limited evidence for carcinogenicity of shiftwork that involves night work
Cancer in Animals
Sufficient evidence in experimental animals for carcinogenicity of light during the "daily dark period" (night)
Overall Evaluation
"Shiftwork that involves circadian disruption is *probably carcinogenic to humans* (Group 2A)."

*See IARC Monographs on the Evaluation of Carcinogenic Risks in Humans. Volume 98. *Painting, Firefighting and Shift Work* (2010).

Table 3. Work Shift Characteristics for Improved Exposure Assignment

Length of shift worked (including start/stop times)
Number of days on/off shift (pattern of shift work)
Type of shift rotation (forward or reverse)*
Speed and frequency of schedule rotation
Number of years working shifts
Quality, duration, timing of light

* "Forward" = day, evening/swing, overnight; "Reverse" = evening, day, overnight

work and breast cancer (Costa et al. 2010; IARC 2010; Fritschi et al. 2011). As noted previously (Costa et al. 2010), these studies relied on either minimal questionnaire data, such as whether or not a participant was ever involved in shift work; assignment of shift work based on occupation only (secondary group data assumption); or in-person interview–derived data on job history. The primary studies often relied on data from nurses or other workers in health-related occupations. However, IARC also reviewed studies on flight-attendant cohorts to support the evidence in the primary studies (IARC 2010).

The two prospective U.S. studies—Nurses Health Study (NHS I and II)—observed elevated and statistically significant breast-cancer risks in women with ≥ 20 years (80% higher risk; NHS II) and ≥ 30 years (40% greater risk; NHS I) of rotating shift work. No statistically significant higher breast-cancer risk was observed in lower-exposure durations of shift work (Schernhammer et al. 2001; 2006). However, even in these prospective cohorts, the exposure detail remained limited to a single question metric: total years working at least 3 nights per month in addition to another shift (day or evening).

Among the other studies assessing breast-cancer risk, exposure descriptors varied substantially. For example, they ranged from whether study subjects had worked at least one night shift per week in the last 10 years to whether they had ever worked a night shift for > 1 year. (For a detailed discussion, see Costa et al. 2010.) In general, positive associations between shift work and breast cancer were observed for females assigned to the groups with the longest duration of exposure, which ranged from just > 3 years to > 30 years. Additionally, although most studies controlled for age, smoking, and body-mass index, the assessment and control of potential confounders or other risk factors remained limited. Control for reproductive factors (age of menses, age of menopause, parity or number of children borne) or other factors (such as family history of breast cancer or socioeconomic status) was lacking in many studies (with the exception of the NHS cohorts).

Other Cancer Risk

In comparison to published studies on breast cancer outcomes, more limited work has been published related to other potential cancers.

In comparison to published studies on breast-cancer outcomes, more limited work has been published on other potential cancers (IARC 2010; Costa 2010). These are summarized below:

- Three studies have been published on prostate cancer, with the highest risk observed for Japanese men self-reporting working rotating shifts (a 3-fold increase based on 31 cases among > 14,500 participants) (Kubo et al. 2006). A Canadian case-control study reported a smaller increased risk associated with working rotating shifts for >34 years (30%) or < 7 years (40%), but no increased risk for the intermediate quartiles (7–34 years) (Conlon et al. 2007).
- Three studies have reported findings associating colorectal cancer with shift work. A positive result (35% increased risk) was reported from the NHS I cohort after 15 years of

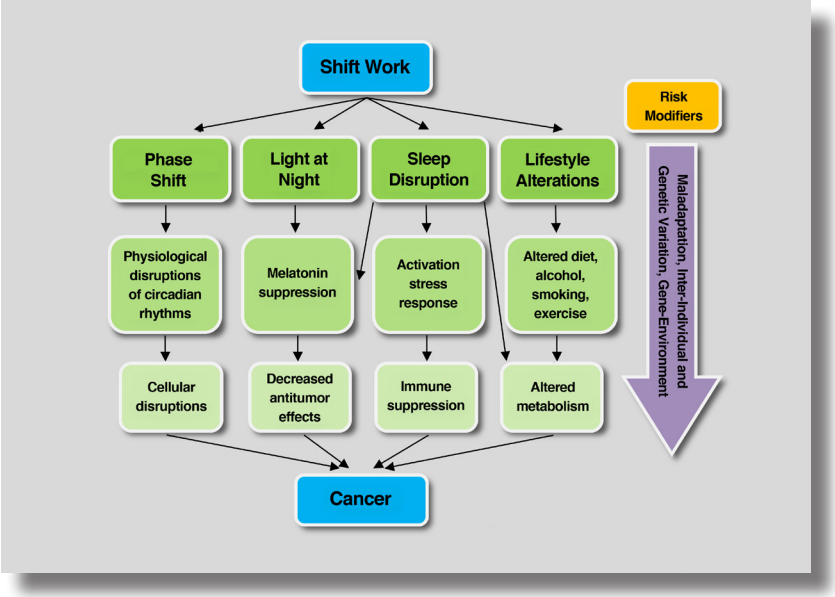


Figure 1. Hypothetical Mechanistic Framework for Shift Work–Induced Cancer (Adapted and Expanded from Fritschi et al. 2011)

exposure to rotating shift work (Schernhammer et al. 2003).

- A single study (from NHS II) reported a nearly 50% increase in endometrial cancer in nurses working rotating shifts for 20 or more years (Viswanatham et al. 2007).
- A single Finnish Cancer Registry–based study reported a small increased risk (10%) for non-Hodgkin's lymphoma among men with 10 years of cumulative night-shift work (Lahti et al. 2008).

Cardiovascular Disease Risk

Studies on the risk of cardiovascular disease (CVD) associated with shift work continue to give inconsistent results.

Studies on the risk of cardiovascular disease (CVD) associated with shift work continue to give inconsistent results (Frost et al. 2009; Haupt et al. 2008; Puttonen et al 2010). Historically, research has focused on estimating the relationship between shift work and ischemic heart disease (either morbidity or mortality). Whereas earlier studies found positive associations between shift work and ischemic heart disease, later studies did not. A suggested reason for these inconsistent results may be that the subset of the worker population who tend to self-select shift work as their preferred work mode already possess certain lifestyle and behavioral characteristics more conducive to heart disease. Similarly, this population subset may self-select out of shift work after acquiring these higher-risk characteristics for heart disease. The relative ability to identify and methodologically account for these characteristics may influence the strength and significance of any research findings. More recent studies have focused on the potential association between shift work and metabolic syndrome and diabetes (Esquirol et al. 2009; Wehrens et al. 2010).

In the case of ischemic heart disease, one recent review identified 16 studies estimating the CVD risk of shift work, with results ranging from no increase (risk estimates at or below unity) to positive (but generally statistically insignificant) associations (risk 1.4–2) (Frost et al. 2009). Studies estimating only mortality from heart disease (fatal heart events) generally appeared to be negative or weak (near or at 1); in comparison, studies estimating combined fatal and nonfatal heart events reported moderately positive associations (Frost et al. 2009). In the combined fatal/nonfatal studies, all but one study reported

Table 4. Research on Shift Work and Workplace Injury: Summary Findings & Issues

Summary Findings
Rotating shifts higher injury risks than regular (day or night) shifts
Shift work including overnights at higher risk
Longer shifts associated with higher risk (> 8 hours, >12 hours)
Inconsistent results relating patterns of risk based on age and/or sex
Common Study Limitations
Large number of cross-sectional studies/surveys
Limited individual exposure completeness and detail (quality and quantity)
Limited number of primary data studies across variety of industrial sectors
Confounding because of differences in workplace characteristics, including coexposures and other concomitant hazards
Assumption of individual risk constant across shift
Causation Hypothesis
Sleep disturbance/alterations disrupting circadian rhythyms
Work-induced changes leading to maladaptation, fatigue, and risk

See reviews: Wagstaff and Lie (2011); Folkard and Tucker (2003)

elevated risks. However several general data issues were raised. These included:

- Inconsistent exposure ("shift work") definitions (often retrospective or estimated from work records, with or without night work)
- Outcome identification (for example, death register or other secondary sources; all heart disease versus myocardial infarction; with or without angina)
- Minimal control for other risk factors (such as hypertension, blood lipids, and smoking)
- Lack of a consistent exposure-to-response curve; (increasing duration of shift work not associated with an increasing risk of cardiovascular disease)

In a recent Finnish general-population cohort, shift work was not associated with an increase in fatal or nonfatal heart disease, retirement/ disability due to heart disease, or diagnosis of hypertension.

In a recent Finnish general-population cohort (> 20,000 adult twins), shift work was not associated with an increase in fatal or nonfatal heart disease, retirement/disability due to heart disease, or diagnosis of hypertension (Hublin et al. 2010). In this prospective study, participants were questioned and followed for over 20 years, with verification of both disease incidence and fatalities. Also, the analysis controlled for over a dozen sociodemographic and lifestyle covariates often associated with shift work (including risk of obesity, smoking, decreased physical activity, and altered sleep patterns). Recent studies on related CVD endpoints, such as ischemic stroke, have reported mixed results (Hermansson et al. 2007; Brown et al. 2009).

Reproductive Health Outcomes

Alternative work schedules (primarily night shifts) have, to a limited extent, been associated with negative pregnancy outcomes (Boznini et al. 2011). A recent systematic review assessed published epidemiology studies on the association between exposure to shift work during pregnancy and the risk of preterm delivery (prior to 37 weeks), low birth weight (< 2500 gram), small for gestational age (< 10th percentile), and pre-eclampsia. The studies varied substantially in study design (most were not prospective),

sample size (from a few hundred to thousands of women), and exposure assessment (definition, type, and timing of exposure to shift work).

In summary, the review reported low effects of shift work on fetal growth (small for gestational age) (risk 1.1) and low birth weight (risk 1.3; not statistically significant). A low, unstable association was found for preterm delivery, which appeared to be highly influenced by study quality; the higher risk associated with shift work decreased from 16% to 3% (not statistically significant) after consideration of issues related to study design. No association was observed between shift work and pre-eclampsia. Overall, increased risk of preterm delivery, low birth weight, or retardation of fetal growth from participation in shift work during pregnancy appears to be limited.

Underlying Mechanisms Between Shift Work and Health Effects

The mechanism(s) by which shift work may cause or enhance adverse health effects remain unclear.

The mechanism(s) by which shift work may cause or enhance adverse health effects remain unclear. However, several recent reviews have attempted to outline potential hypothetical frameworks to fit the available experimental data (Arendt 2010; Fritschi et al. 2011; IARC 2010). Figure 1 outlines this framework for cancer effects (but it could potentially apply to other health effects). It has been theorized that one or more complex related pathways associated with biological rhythms (for example, the circadian cycle) may play a role in disease causation. Daily biological processes—including sleep/wake cycles, hormone levels, immune responses, and other bodily functions (such as temperature, blood pressure, and heart rate)—follow a "biological clock." If this endogenous biological clock gets out of sync with the local environment because of behavior patterns, sleep/wake cycle disruptions, or other factors like shift work, misalignment of this circadian cycle occurs. This misalignment can negatively influence downstream processes and increase the likelihood of disease. The varying ability of individuals to adapt to frequent, repeated, or cumulative changes in their work schedules may indicate their inherent strength or weakness to respond to such disruptions.

Shift Work and Its Relation to Injury

Relatively strong evidence indicates that various forms of off-hours work schedules—including night, evening, rotating, or irregular shifts—are associated with an increased risk of workplace injury (Folkard and Tucker 2003; Wagstaff et al. 2011; Wong et al. 2011). Table 4 summarizes the basic findings and limitations of two recent systemic reviews. As with cancer-outcome studies, exposure data on shift work or work hours are often poorly reported in injury research or surveillance systems. Additionally, because a majority of injury studies do not have a particularly robust design (including simple surveys or self-reported accidents), it can be difficult to ascertain temporal considerations (exposure duration or other factors preceding an injury) for estimating risk and determining causality. A recent review by Wagstaff et al. (2011) reported risk-estimate ranges for the following four types of shift work, extracted from 14 (of 400 possible) studies that met quality inclusion criteria:

- Work shifts over 12 hours: 1.3 – 3.3 (based on 4 studies)
- Work shifts over 8 hours: 1.3 – 2.0 (based on 4 studies)
- Night work: 1.3 – 1.9 (based on 3 studies)
- Rotating shift work: 1.2 – 2.0 (based on 4 studies)

Although this is a limited sample, in general, an increased risk of injury (in the range of 30–100%) was associated with shift work. However, these studies varied substantially in factors such as risk measure,

industry/occupation type, accident type, comparison group, data sources (exposure and outcome), and covariates (such as age or other individual characteristics).

An earlier review by Folkard and Tucker (2003) attempted to evaluate the relative risk of reported injuries across shifts, with a potential crude increase in risk of injury moving upwards clockwise—from a morning baseline to evening (18%) to night (30%). These results were derived from 10 studies. Additionally, this review reported a linear decline in injury risk across the duration of the night shift (with a peak at the second shift hour and the lowest by the final hour) and an increasing injury risk across the duration of four successive night shifts (from a first-night baseline upwards to a 36% increase on the fourth night).

As with adverse health outcomes, shift work has also been found to induce changes in regular sleeping schedules and disruption of normal biological rhythms, leading to sleepiness and fatigue.

As with adverse health outcomes, shift work has also been found to induce changes in regular sleeping schedules and disruption of normal biological rhythms, leading to sleepiness and fatigue (Kling et al. 2010; Lombardi et al. 2010). However, quantifying this effect remains difficult because of limitations in injury surveillance, complementary work-hour reporting, shift characteristics (such as task, coworker, and supervisor interaction), worker health status, sleep patterns, and other indicators of maladaptation. In particular, future work on individual characteristics that influence long-term tolerance or intolerance to shift or rotating-shift work may assist in identifying working conditions, scheduling recommendations, and injury-intervention programs on an industry-specific basis (Costa 2003).

Potential Influence of Shift Work–Related Health Effects on the Electric Power Industry

A relatively large and diverse body of scientific literature describes the potential relationship between shift work and various negative impacts on worker health. However, disease-specific relationships remain both inconsistent and complicated by the multifactoral nature of chronic disease and injury causation. The magnitude of the potential association, as well as the demonstrated causality, varies by health outcome. Nevertheless, the potential for regulatory agencies to influence occupational guidelines, monitoring, and other types of oversight may continue to grow—as witnessed in parts of the European Union, particularly as public health agencies such as WHO/IARC weigh in via scientific review and comment (IARC 2010; Stevens et al. 2011).

It remains to be seen to what extent recent scientific findings will influence industry regulation or practices in the electricity-generating sector.

It remains to be seen to what extent recent scientific findings will influence industry regulation or practices in the electric power industry. To date, primary research on power-generation, transmission, or related utility worker populations have not been reported. Extrapolating current scientific findings to the power sector is limited by several questions, including

- How does the current knowledge base relate to past and current practices among the occupational population in the electric power industry?
- Does shift work present a unique concern to this industry, as compared to the previously studied worker populations (the focus of which has been the healthcare or manufacturing industries)?
- What is the current potential for increasing occupational health and safety regulatory interest in the electric power industry?
- How established will research findings need to be in order to develop effective intervention or improved medical and surveillance strategies?
- In the end, will it be possible to identify or quantify an "unsafe" work schedule within the electric power industry's occupational framework?

The objective of this brief report is to inform stakeholders in the electricity-generating sector of current scientific knowledge on worker health and safety risks associated with shift work in order to support future research planning; proactively inform health and safety regulation; and, ultimately, maintain and improve worker health.

Future Occupational Research Directions in the Electric Power Industry

The ability to reduce the risk of occupational contributions to short-term health effects, acute injuries, and chronic disease derived from worker exposure to shift work may require a range of additional scientific studies. The continued focus on shift work as a potential cause for a range of adverse health outcomes indicates that proactive study in settings more relevant to power generation and delivery may help determine what aspects of shift work could increase worker risk to the outcomes summarized above. Additionally, even limited industry-specific studies could aid in the extrapolation of broader scientific findings to sector-specific occupational exposure scenarios and to the development of intervention programs in areas identified as at higher risk.

The potential carcinogenicity of shift work may be one of the main health risks of concern.

The potential carcinogenicity of shift work may be one of the main health risks of concern. But shorter-term outcomes, such as injury prevention and worker safety, may provide more immediate opportunities for sector-targeted research and intervention. The prohibitive cost, logistical, and temporal constraints on developing a large, long-term, sector-specific prospective cohort to monitor lifetime worker health outcomes limit the ability to robustly quantify risks from cancer and other common chronic diseases. Formally characterizing the potential for shift-based hazards and describing industry-specific shift definitions, occupational settings, and task-specific populations at potential risk may be an initial step. Initial studies would need to formally identify the detailed data requirements to establish reliable exposure estimates (for example, range, type, and extent of shift work) for standardized compilation and comparison to injury surviellance. Additional research areas may include detailed pilot or feasability studies to identify the underlying causes of maladaptation to sector-defined shift work—including the collection of detailed data on work behavior, lifestyle, sleep disruption, light exposure, and biological markers of stress, melatonin, circadian rhythm, or susceptibility.

In summary, occupational settings requiring shift work or long work hours are not new phenomena. However, growing scientific evidence on—and potential regulatory interest in—associations between certain aspects of shift work and negative health outcomes indicate a need to continue evaluating adverse effects in the electric power industry.

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Export Control Restrictions

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