# Cost efficiencies of large-scale integrated dairy production and waste management systems

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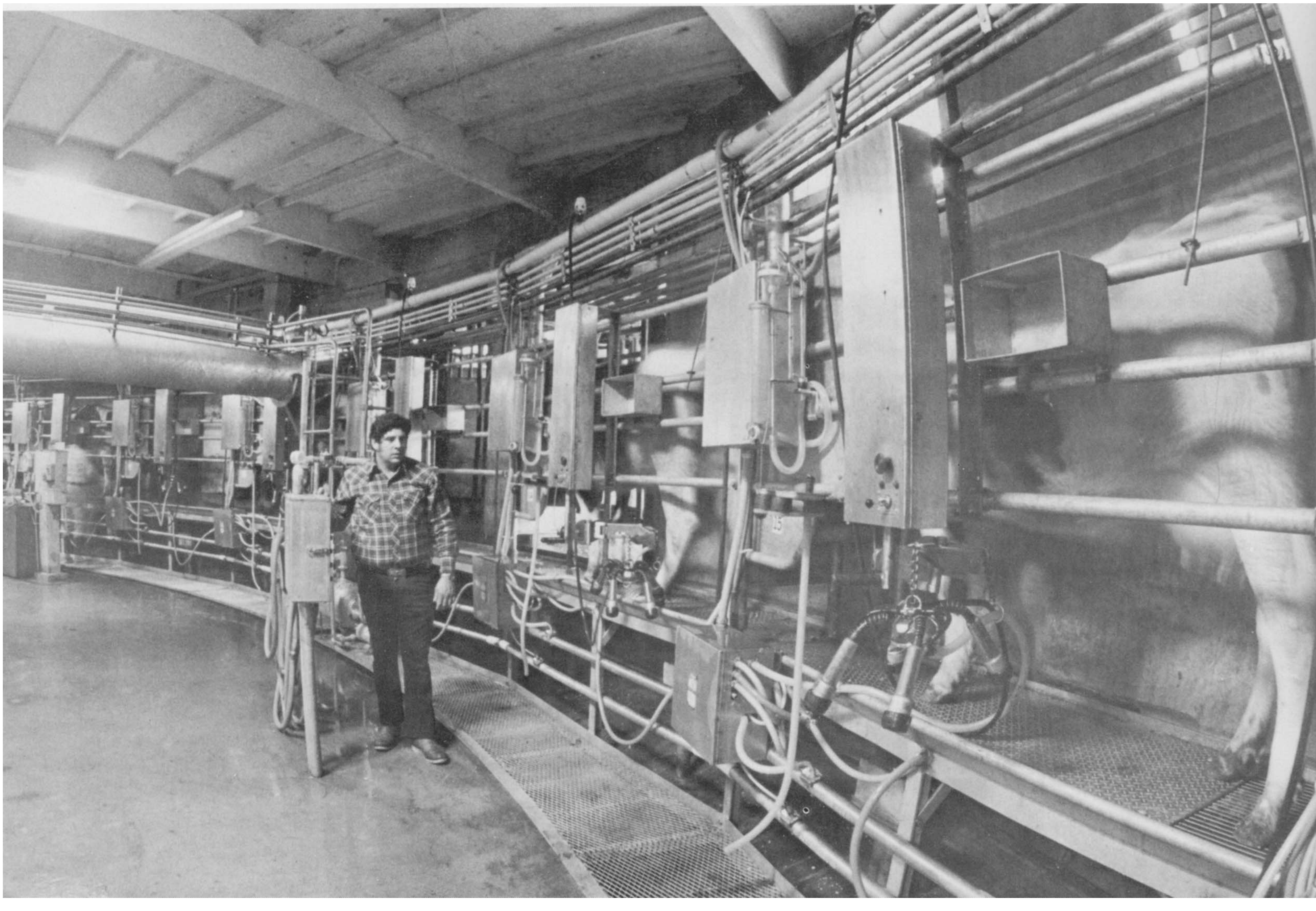
Livestock production in California and much of the United States has been shifting from small-scale diversified units to large-scale confinement operations feeding high-concentrate rations. This attempt to increase production efficiency has sometimes resulted in waste-management practices inconsistent with increasingly stringent environmental quality regulations.

The concentration of large-scale dairy operations in the Chino Basin east of Los Angeles is a case in point. The Santa Ana Regional Water Quality Control Board brought Chino dairies under control in 1972 in response to serious water-quality problems purportedly caused by waste management and disposal. The Phase I and II regulations, which control runoff and the application of manure to land, resulted in higher costs to the regulated dairies. Dairymen are uncertain about the possible nature and enforcement of future regulations, and they lack knowledge of waste management/production technology capable of satisfying an environmental quality objective of zero degradation from dairy wastes. Although the impact of waste-control regulations on the cost structure and future economic viability of Chino dairies is the focus of this report, the results have implications for similar milk-producing areas.

Analysis of efficient large-scale dairy production in the context of environmental quality objectives involves simultaneous consideration of the role of waste management in the production of milk and the underlying cost structure. To this end, short- and long-run costs for large-scale dairying, including waste management, were estimated. The economic-engineering approach was utilized for the analysis. The dairy was disaggregated into five stages: milking, housing, feeding, waste management, and management and record keeping. In the first three stages, costs were synthesized from detailed analyses of elemental production specifications and restrictions. Particular emphasis was placed on new semi-automated milking techniques and alternative feeding programs. Cost estimates for the



waste-management stage were synthesized largely from published sources, but necessary design paramater modifications were made to assure process compatability with dairy wastes. On-dairy costs in the form of commercial collection services, additional labor, and dairy facility modifications were estimated for each treatment and disposal method.

The dairies considered in this study were organized as specialized single-enterprise units producing only fluid milk. Alternative combinations of milking parlor and housing configurations, feeding programs and rations, and equipment and labor complements yielded over 200 different complete dairies. From these, 14 single-parlor dairies with capacities ranging from 375 to 1,200 cows for two milking shifts were modeled. Short-run average costs were estimated for each of these model dairies. A combination of single-parlor dairies into multiple-parlor configurations yielded 15 more dairies in the 1,200 to 3,600 cow herd range.

Four waste disposal treatment processes were selected for analysis as having "good" volume reduction, stabilization, and resource recovery capabilities. Three of these—composting, anaerobic digestion, and refeeding—are biological processes; the fourth, incineration, is a physical/chemical process. Each is depicted as a component of the general dairy waste management system in the figure.

**Composting** is a biological stabilization process in which the organic content of raw waste is partially stabilized before land application. Volume reduction, concentration of plant nutrients, and increased water holding capacity are characteristics of composted manure. Commercial composting operations in the Chino Basin have proved to be an effective waste management alternative. Although composting technology is well advanced, market development is a serious limitation to widespread use of composting.

**Anaerobic digestion** is a liquid waste treatment process in which organic matter is stabilized biologically in the absence of oxygen. Methane gas, which is produced during organic degradation and stabilization, can be recovered and utilized to produce electricity. Anaerobic treatment methods are either unmanaged anaerobic lagoons (common to livestock operations) or controlled complete-mixed reactors (common to municipal treatment). This latter system, in which temperature and mixing are controlled to promote optimum conversion and production of methane, is analyzed in this study.

**Refeeding manure** to animals offers a promising new extension of material recovery. Most of the original nutrients available in the dairy ration escape digestion. Processing the manure can enhance the nutritional value of waste by increasing the availability or concentration of protein and energy or both. Furthermore, processing can control ingestion of hazardous substances such as heavy metals, pesticides, drugs and pathogens that may be present in the manure. Although three basic manure refeeding process technologies are available, only the *Cereco Process* is evaluated in this study.

**Incineration** is a process of burning combustible matter under controlled conditions. Originally designed to reduce waste to inert substances, waste-heat recovery has become an important design consideration in an effort to capture the energy contained in wastes. Both conventional refractory wall incinerators and waterwall incinerators may be used for heat recovery. However, only waterwall units are evaluated in this study because of reduced volumetric capacity and required equipment to control air pollution from exhaust gases and particulate matter.

## Empirical results

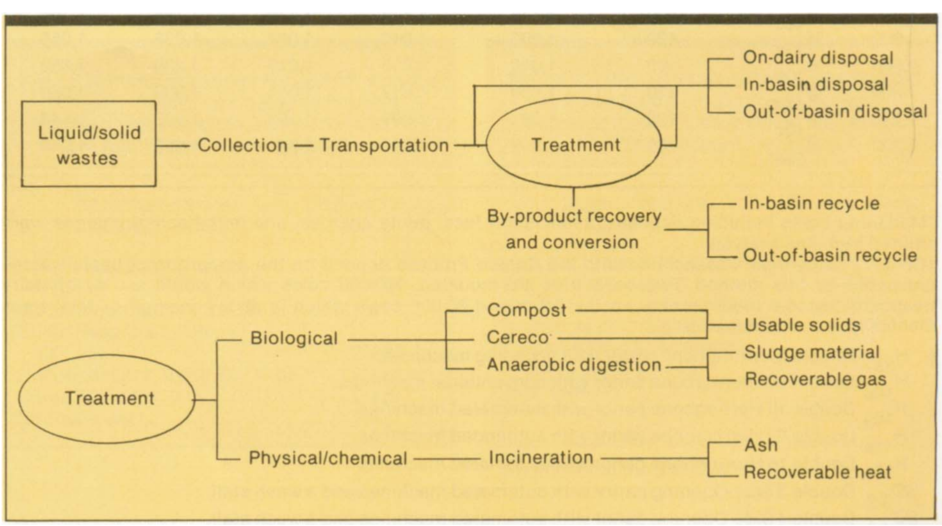
The table summarizes average total costs corresponding to the least-cost dairy configurations for alternative design capacity herd sizes and waste management methods. Both semi-automated milking systems and group-feeding programs offer potential efficiencies for large-scale dairies. The dry lot/incineration system was the least-cost dairy housing/waste disposal alternative considered. Significant economies of size are revealed in the 375 to 750 cow range and only slight cost reductions for dairies thereafter. Specifically, unit costs for the 750-, 900-, and 1,200-cow dairy are approximately equal at $1,001, $1,002, and $999 per cow respectively.

These results are striking when compared with previous studies of economies of size in dairying. Economies of size are available for herd sizes five times greater than previously found. Consideration of new semi-automated milking parlors is primarily responsible for this conclusion. The largest portion of economies is realized at 450 cows—the first herd size to employ a semi-automated milking system. Over 60 percent of the reduction in unit costs are attained between the nonautomated 375-cow dairy configuration and the automated 450-cow dairy. Further reductions in unit costs to the 750-cow size are available from better capacity utilization of the milking parlor and alternative milking techniques.

Although the costs presented in the table are for dairies having from 375 to 1,200 cows, several dairies in the Chino

**Left: Automated milking systems—such as this carrousel unit at the A & A dairy near Tracy—offer dramatic efficiencies in dairy operations. This system permits four men, working 16½ hours in two 2-man shifts, to milk 700 cows three times a day. As the carrousel rotates, cows are moved step-by-step through the milking process at the rate of 130 cows per hour. Here, Don Allegre, who owns the dairy with his father, Frank, remains stationary as the cows are moved to his station.**

**Right: The general dairy waste management system.**



area have more than 1,200 cows and the largest has approximately 3,600 cows. Costs for these large multiple-parlor dairies can be estimated by combining two or more single-parlor dairies. Consolidation of certain production activities among the combined dairies by substituting larger, more efficient technology (*i.e.*, technologies with more favorable cost-volume relations such as general dairy and refrigeration equipment and management) and more complete capacity utilization offers an opportunity to further lower production costs.

Because most annual dairy costs (85 to 90 percent) are continuously variable (*i.e.*, vary with cow numbers), potential cost reductions from fuller capacity utilization and consolidation are small. The average total annual cost for the 1,200-cow dairy operated at capacity under specifications of this study was $999. We estimate that the maximum advantage for the 3,600-cow dairy would be $5 per cow for an average total annual cost of $994.

The impact of waste management on dairy production costs can be examined by calculating costs for least-cost dairies excluding waste management. We specify total annual dairy costs exclusive of waste management for each technically feasible parlor configuration for both dry-lot and free-stall housing.

A comparison of costs shows that dry-lot housing yields $25 to $30 lower unit-production costs than does free-stall housing for all herd sizes. This difference in housing costs has a significant impact on the integrated waste-management system selected as the least-cost alternative. Housing design is the major determinant of the applicability of a particular treatment and/or disposal method. If waste treatment and disposal costs are minimized and the resultant methods simply tacked on to the dairy, a suboptimal over-all system would be obtained. By simply minimizing cost of treatment and disposal, Cereco 160,000 is least cost, followed by Cereco 80,000, incineration, sanitary landfilling, and anaerobic digestion. Under the integrated dairy production system, however, the Cereco 160,000 system moves from first to fourth ranked, the Cereco 80,000 system remains second ranked, incineration moves from third to first ranked, sanitary landfilling moves up a position to third ranked, and anaerobic digestion remains unchanged in the fifth ranked position.

**Short-Run Average Costs for Least Cost Dairies at Capacity, by Herd Size, Housing Classification and Waste Management System***

| Herd size | Parlor§ | Housing size | Dry lot: Incineration | Dry lot: Sanitary landfill | Dry lot: Cereco 80,000* | Free stall: Cereco 160,000† | Free stall: Anaerobic digestion |
|---|---|---|---|---|---|---|---|
| | | number of cows | dollars per cow | | | dollars per cow | |
| 375 | $H_{5s}$ | 100 | 1,065 | 1,073 | 1,068 | 1,098 | 1,116 |
| 400 | $H_{5s}$ | 80 | — | — | — | 1,089 | 1,106 |
| 450 | $SO_{3\text{-}2}$ | 120 | 1,024 | 1,032 | 1,026 | 1,057 | 1,076 |
| 500 | $SO_{3\text{-}2}$ | 100 | 1,041 | 1,049 | 1,043 | 1,073 | 1,090 |
| 600 | $SO_{3\text{-}2}$ | 120 | 1,019 | 1,027 | 1,021 | 1,050 | 1,069 |
| 625 | $SO_{3\text{-}2}$ | 100 | 1,019 | 1,027 | 1,022 | 1,053 | 1,073 |
| 700 | $SO_{4\text{-}2}$ | 80 | — | — | — | 1,039 | 1,059 |
| 750 | $SO_{4\text{-}2}$ | 100 | 1,001 | 1,009 | 1,003 | 1,033 | 1,053 |
| 875 | $H_{10c}$ | 100 | 1,114 | 1,122 | 1,116 | 1,144 | 1,164 |
| 900 | $H_{12a}$ | 120 | 1,002 | 1,010 | 1,004 | 1,035 | 1,055 |
| 1,000 | $H_{10a}$ | 100 | 1,010 | 1,018 | 1,012 | 1,039 | 1,059 |
| 1,050 | $H_{12a}$ | 120 | 1,009 | 1,017 | 1,011 | 1,039 | 1,060 |
| 1,125 | $H_{10c}$ | 100 | 1,091 | 1,099 | 1,193 | 1,123 | 1,143 |
| 1,200 | $H_{16a}$ | 120 | 999 | 1,007 | 1,001 | 1,028 | 1,049 |

*Marketing costs including licenses, association fees, quota charges, and milk hauling charges were omitted from this analysis.
†On-dairy adjustments associated with the Cereco Process depend on the proportion of basin wastes processed by this method. Two capacities are modeled, 160,000 cows which would satisfy off-dairy treatment/disposal requirements for the basin and 80,000 cows which is about one-half of total treatment/disposal requirements.
§ $H_{5s}$ Double 5 Herringbone parlor with swinging machines.
$H_{10c}$ Double 10 Herringbone parlor with conventional machines.
$H_{10a}$ Double 10 Herringbone parlor with automated machines.
$H_{12a}$ Double 12 Herringbone parlor with automated machines.
$H_{16a}$ Double 16 Herringbone parlor with automated machines.
$SO_{3\text{-}2}$ Double 3 Side-Opening parlor with automated machines and a wash stall.
$SO_{4\text{-}2}$ Double 4 Side-Opening parlor with automated machines and a wash stall.

## Implications

Under the present industry structure, environmental quality controls place considerable stress on the competitive situation of the Chino dairies. However, it is not certain—as some suggest—that all dairies will be forced out of business or will relocate out of the Chino Basin. According to the analysis presented in this study, enforcement of environmental quality controls need not raise the costs of dairy production in the long run. The recent development of improved dairy production techniques, coupled with scale economies available from regional waste treatment and disposal methods, potentially allow for a substantive change in the Chino dairy industry cost structure. The cost of milk production theoretically could decline from present levels while production methods could still comply with environmental quality controls. Herd sizes could also increase as dairies capture greater economies of size.

Care must be taken not to misinterpret the above conclusions. The costs derived in this study are not averages of existing Chino dairies but are estimates of the level of costs associated with modeled dairy configurations using the most modern dairy technology available. However, the potential cost savings suggest that incentives exist for adjustments leading to a decline in cost and an increase in average herd size. With the assumption that milk and input price relations remain relatively unchanged, the adjustments could enhance and perhaps preserve a viable dairy industry in the Chino Basin. A dramatic change in the industry structure would, however, be necessary to support this conclusion. Credit availability and managerial capabilities would probably prevent many of the existing dairies, particularly smaller ones, from making the required adjustments, but the displaced resources could be consolidated into fewer but larger firms.

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