AN ALTERNATE WAY

by

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Richard Hillman was born in Fairview Hospital, Fairview, Montana, April 6, 1946, and was too impatient to wait for the doctor.

He was raised on a farm seven miles west of Fairview where he did his daily chores and worked summers until his graduation from high school.

After his graduation, he chose from three principle appointments to service academies and attended the Naval Academy at Annapolis, Maryland. After seven months he found that military life was not something he wanted to be molded into after his previous life of freedom, so he resigned and went directly to Graceland College, Lamoni, Iowa, and studied in a pre-architecture course for three semesters.

After Graceland, Richard attended Montana State University School of Architecture for the next four years with only one quarter off to help his family back on the farm.

Richard then moved to Colorado Springs, Colorado, where he worked in an architectural and planning office for two years. During this time he studied the real estate profession and obtained a license to sell. He also attended the University of Colorado, Colorado Springs, and studied business during this time.

After two years as an employee, Richard and a partner established a development company and were ready to build an apartment complex when the first national energy crisis arrived, leaving them unable to obtain a building permit, thus closing their company.

Richard was asked by his family to move back to Montana at this time and since he had obtained part ownership in the family farm in the previous year, he went. For the next seven years he managed the farm while he also did work as a designer, draftsman, and contractor, and served the community as a director on a Section 8 housing project.

Attending Montana State University again, Richard will have, upon successful completion of this project, completed the requirements for a Bachelor of Arts degree in Architecture.
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ABSTRACT

It is now and will be ever more so very important to use our energy supply to its highest potential. In this project I have attempted to study a varied cross section of uses of energy and through synthesis develop an optimum approach to energy use by light construction and to an extent by farms.

The ancient peoples of this continent used only renewable energy and by using earth sheltered construction and proper siting were able not only to survive but to do so much more comfortably than the early white man.

In this project, the solution to the farm home may be the first house designed in this country (for this climate) that actually vents energy. It is even expected to do this in the winter months of December and January. This house also has adaptability to the changes in weather and season designed into it through the use of operable insulated shutters.

The overall energy needs of the entire farm system are to be supplied by a wind generator, with storage handled by producing hydrogen to run fuel cells. The machinery can also run on this hydrogen which means that no nonrenewable resources must be used for energy needs. It also means that the land does not have to be raped to produce energy.

The entire system, in whole or in parts, provides us with an alternate way to supply our needs while providing ourselves an enhanced lifestyle over that which we now experience.
THESIS STATEMENT

In order to sustain our present way of life in the United States and hence the world, we need new methods of energy production and use. I wish to study some of these.
It is my wish that I might have vision to see, and courage to do, so that the way of life we know can be enhanced rather than weakened, and that is my reason for studying, trying to find new ways to use with the old, and yet fit them into the ecosystem in which we live. That is the reason for this thesis.
There was a sunny, savage land
Beneath the eagle's wings
And there, across the thorns and sand,
Wild rovers rode as kings.

Badger Clark

(Brown and Felton, 1955:12)
"In the beginning the surface of the earth was all water and there was darkness" (Beckwith, 1930:1). Lone Man and First Creator were walking about on the surface of the water.

"I have been considering," said First Creator, "that you and I should create some land." Lone Man agreed. They asked the mud-hen what food it had for its subsistence. The bird told them, "I dive under the water and there is land and I eat the dirt down there." They said, "Dive down and bring us up a sample." Some time later the bird came up with a little mud. Four times it dived and still there was only enough to fill one hand. Lone Man rolled it into a ball and gave half to First Creator and kept the other half. He said, "We will make a dividing point and leave a river and you may choose which side you will create." First Creator chose the south side, Lone Man took the north. They built the land, the south by First Creator, the north by Lone Man. First Creator made some places level, ranges of hills, ranges of mountains, springs, timber and coulees with running streams. He created buffalo,—made them all black with here and there a white one. He created Rocky Mountain sheep, deer, antelope, rattlesnakes,—all the animals that used to exist here. Lone Man created mostly flat land with many lakes and ponds grown with bulrushes and with few trees. He created cattle—some white, some spotted, some red, some black—with long horns and tail, and the animals like the badger and beaver that live in the water and the duck and geese that swim on the water, also the sheep of today. Then they met on the north side of the river and reviewed the creation that they had completed. Both believed his creation to be the better. They examined first what First Creator had made and Lone Man said the land was too rough. First Creator said, "No, I did this for the safety of the creatures. When they are in danger from a hard winter they will have protection in the timber and shelter in the coulees." He showed him the tribes of people that he had made (the Indians). But Lone Man was displeased with First Creator's work. He showed him how level
the land was on the north side of the river, dotted with lakes and strewn with boulders and treeless so that the eye could see far away. First Creator however was dissatisfied. He said, "In the winter there is no protection, in time of war there will be no place to hide."—"No," argued Lone Man, "they can see the enemy far away and hide in the bulrushes beside the lakes." He pointed out the beauty of the cattle. First Creator found them too weak to pull through the winter, with too little fur, too long horns in comparison with the protection of the buffalo against the cold. So he disapproved of Lone Man's creation. It was agreed to let the people live first on the creation of First Creator then the generation to come should live on the cattle created by Lone Man, hence that the cattle should drift back to the far east where he had created people out of his own breath, light-complexioned and well worth looking upon, who should come westward later and inhabit the land with the first people (Beckwith, 1930:8-9).

This ancient story of the creation as the Mandans believed it shows a startling awareness of the effects of the land types on the climate and also explains the life habits of the Mandan, Hidatsa, and Crow Indian nations which

In the prehorse era the Mandans, Hidatsas, and Crows successfully held a vast area from the Cannonball to the Yellowstone, up that stream to the Powder, and east to the Little Missouri. Not until the advent of mounted nomads, equipped with firearms, was their hegemony over this region threatened (Bowers, 1965:214,216,484,489; Wilson, 1917:1). (Plates 1 and 2)

In all ancient myths and customs of people there is a tale of divine guidance in the construction of their sacred buildings. The Mandans were no different as they have myths represented in a ceremony by an old man.
This "Nu-mohk-muck-a-nah" (first or only man) was undoubtedly some very aged medicine man of the tribe, who had gone out upon the prairies on the previous evening, and having dressed and painted himself for the occasion, came into the village at sunrise in the morning, endeavoring to keep up the semblance of reality; for the traditions of the Mandans say, that "at an ancient period such a man did actually come from the West, that his skin was white, that he was very old, that he appeared in all respects as has been represented; and as has also been stated, that he related the manner of the destruction of every human being on the earth's surface by the waters, excepting himself, who was saved in his "Big Canoe" by landing on a high mountain in the West; that the Mandans and
all other nations were his descendants, and were bound to make annual sacrifices of edged tools to the water, for with such things his "Big Canoe" was built; that he instructed the Mandans how to make their Medicine Lodge, and taught them also the forms of these annual ceremonies, and told them also that as long as they made these annual sacrifices and performed these rites to the full letter, they would be the favoured people of the Great Spirit, and would always have enough to eat and drink, and that so soon as they departed in the least degree from these forms their race would begin to decrease and finally die out (Catlin, 1967:72).

The medicine lodge remained, built in the ancient or early Indian style until the extinction of the Mandan people, although their house style evolved with incursions of new tribes. This shows the power of religious beliefs over people's actions and life patterns.

With this information in mind, I would now like to investigate the building style and location of what are generally known as the Mandans.

900 A.D. MANDAN TRADITION

By 900 A.D. agricultural groups had begun arriving in the area (Missouri River bottom from the Cannonball River to Knife and Heart Rivers).

These first village Indians to occupy the valley of the upper Missouri lived in small settlements of twenty to thirty houses--sometimes even fewer in the north--grouped loosely along terraces overlooking the river. The houses were rectangular, averaging twenty-five by thirty-five feet (though many were larger), their floors one to four feet below
the surface. In the earliest the roofs were supported by posts set into the ground on all four sides; later, only the long walls were so constructed. There is no way of knowing for sure whether the roofs were covered with sod, like those of the historic earth lodges, or merely thatched. A fire pit was located near the entrance, midway between the two long walls. A low passageway extending about eight feet beyond the end of the house led in from outdoors. Typically, the houses were oriented in a northeast-southwest direction, and the entrance was on the southwest end (Wedel, 1961:169-72; Wood, 1967:119-24; Lehmer, 1971:66, 69-70).

These early village peoples depended for subsistence about equally on horticulture and hunting, with food-gathering a minor source. Judging from the quantity of bones, bison was their principal game. The presence of fishhooks in the sites suggests that some reliance was placed on the sturgeon and catfish found in the Missouri. Pottery and an assortment of tools and weapons, some of stone, some of bone and antler, afford us an insight into the subsistence patterns and general material culture of these early Plains Villagers, but beyond that it is impossible to go on the basis of our present knowledge. From the rarity of burials it may be inferred that they exposed their dead on scaffolds, as did the historic Mandans and Hidatsas, and that the bones were subsequently scattered (Wedel, 1961:172-73; Bruner, 1961:193-94; Lehmer, 1971:70).

1300 A.D. HISTORIC MANDAN

By 1300 A.D. the tribes living in this area were considered to be the ancestors of the Mandan-Arikara-Hidatsas peoples. Many changes occurred with the migrations of and intermingling of these varied people.
Perhaps in the long run the most radical change wrought in Mandan culture by association with the Arikaras was the shift from long-rectangular to squarish or round houses. The first migrants from the Central Plains built square houses with rounded corners; gradually these came to be round houses with flattened sides. At Huff nearly all the houses are of the rectangular variety, more or less aligned in rows paralleling the river, but one excavated house was square, its roof supported by four center posts like those used in the historic circular earth lodges. Some time between the building of this house and the arrival of the first Europeans, the Mandan builders underwent a complete conversion to the Arika style of house. It had much to recommend it. A circular building with a fire pit in the center would have been easier to heat than a long-rectangular one with a firepit near one end. As Donald Lehmer remarks, the back part of the old-style Mandan houses must have been "miserably cold" in the harsh Dakota winters (Wood, 1967:133-35; Lehmer, 1971:162).

During this period the villages grew in size, shrunk in number, and became fortified.

Not only were the villages larger and more heavily fortified than ever before, but they were lived in for longer periods of time. Huff is a case in point. This site, located eighteen miles down the river from the city of Mandan, has been studied more intensively and over a longer period of time than perhaps any other site on the upper Missouri. Believed to have originally had 115 houses, it must have had a population of more than a thousand, crowded into a space of about ten acres. It was protected by a more or less rectangular ditch and palisade extending around three sides of the village and equipped with numerous bastions. The construction and maintenance of such a defensive system, together with the sheer density of the population, implies stronger social controls than would have been needed in the smaller sites down-river (Wood, 1967:131-32; Lehmer, 1971:127).
Edward S. Curtiss, a modern student of the three tribes, has made some observations about these peoples.

His observation is particularly valid in reference to the kind of dwellings the Three Tribes occupied. Once the rectangular earth lodge had been given up by the Mandans, all three lived in basically the same type of structure. Most white observers commented on the similarities. Bradbury, who described in detail the Oto lodges he saw on the Platte River, even went so far as to forego any description of those of the upper Missouri tribes, on grounds that they were practically the same (Wedel, 1961:158-60; Lehmer, 1971:55). Although it is unlikely that many white visitors actually witnessed the construction of an earth lodge, most of them made some effort to explain how it was done. The first step was to dig a foundation to a depth of one or two feet. Next, four large posts twelve to fifteen feet long (above ground) were set up in the form of a square, about ten feet apart. Then along the outer perimeter of the foundation thirteen to sixteen shorter posts, five or six feet long, were set up, and stringers were laid from one to another of these posts, which were usually forked. Across the four central posts, which were also forked, substantial beams were laid. Rafters were then laid from these beams to the stringers, close enough together so that the upper ends touched. Lighter poles were erected between the posts that formed the outer ring. If the design of the lodge called for an atutish area, other slanting poles would be leaned against the stringers from the ground. When the framework was complete, a six-inch mat of willow boughs was laid over it. A layer of dry grass came next, and then a layer of earth two or three feet deep. Catlin spoke of the whole structure being covered with hard, waterproof clay (Wedel, 1961:159; Wood, 1967:8).
Plate 3

FIG. 1. MANDAN HOUSE. (After Morgan.)

Plate 4

Plate 5

Plate 5

an alternate way
This construction could result in an approximate $R$ value of 12 plus an $M$ factor which would allow for a 36-hour time lag. The ground floor would also probably stay at $40^\circ$ F through the winter. Thus it would not take tremendous amounts of heat to keep the lodge livable.

There were minor tribal differences in the construction of earth lodges. The orthodox Mandan method was to allow the rafters to extend only slightly beyond the large central beams and then to cover most of the open space at the top with horizontal poles, leaving only a smoke hole at the center. By contrast, the other tribes (and to some extent the Mandans also) allowed the rafters to meet, like tipi poles, and then sawed them off to leave a chimney hole, which also provided most of the light that reached the interior of the lodge (Wedel, 1961:160; Wood, 1967:8; Lehmer, 1971:55). The manner of constructing the entry differed slightly, too, but basically it was a rectangular passage covered with earth, seven feet wide and extending ten feet beyond the lodge proper. Earth lodges varied from thirty to sixty feet in diameter—some were larger still—and they
were said to last about ten years. Since they were owned by the women (properly speaking, by the clan, but inherited in the female line), the architects and builders were women; men helped put the heavy timbers in place (Lehmer, 1971:54).

In the center of the lodge floor was a fire pit four or five feet across, sunk a foot or more in the floor and curbed with stone. Around the perimeter were the beds, described as rectangular boxes of hide stretched over a pole framework, each with a hole in the side to admit its occupants. From the outer ring of posts hung the personal effects of the head of the household—his shield, bow and quiver, war club, tobacco pouch and pipe, medicine bag, and headdress. From the central posts were suspended the cooking equipment and other household necessities. A flap of hide hung over the entrance to the lodge proper. There was also usually a deflector of some sort to prevent the cold winter wind from entering the lodge directly. After the acquisition of the horse, the Indians took to keeping their favorites inside the lodge on cold nights, and an area to the right of the entrance was reserved for them. On the outside of the lodge might be seen household articles, buffalo skulls, sledges, and an old bullboat or a covered wicker frame that could be placed over the smoke hole in rainy weather (Wedel, 1961:161).

This description applies mainly to the summer villages, in which the Indians spent the greater part of the year. For three or four months during the coldest weather they could retire to their winter villages in heavily timbered bottom lands. The winter lodges were much the same as those just described but smaller; some authorities say they were more nearly conical in shape. Two other types of dwelling were used by the village Indians. On their hunting expeditions they lived in skin tipis of the well-known type associated with the nomadic Plains tribes, and when engaged in trapping eagles they occupied special eagle-trapping lodges, which were tipi-shaped cones of poles, sometimes equipped with the four center posts of the typical earth lodge. Elderly people who had no children or did not wish to live with them and who found the standard earth lodge too hard to keep up might build for
themselves a modified form of the eagle-trapping lodge. All four types of habitation showed a good deal of individual variation and some minor changes as time passed (Meyer, 1977:60-2).

Verendrye, a French fur trader, visited the Mandan nation in order to establish trade in 1738. Following is his account of the Mandan village or fort of that time.

Many people came to meet us but nothing in comparison with what appeared on the ramparts and along the trenches .... Their fort can only be gained by steps or posts which can be removed when the enemy threatens .... If all the forts are alike, they may be called impregnable to Indians .... Their fortifications are not Indian .... Their fort is full of caves in which are stored such articles as grain, food .... ... I walked about .... their fort .... there were one hundred and thirty of them [huts]. All the streets and squares very clean, the ramparts very level and broad; the palisades supported on cross-pieces mortised into posts of fifteen feet. At fifteen points doubled are green skins which are put for sheathing when required, fastened only above and in places where needed. As in the bastions .... at each curtain well flanked .... The fort is built on a height in the open prairie with a ditch upward of fifteen feet deep and fifteen to eighteen feet wide .... The Sieur Nolant and my son arrived [from the other village] .... The fort is on the bank of the river, as large again as this. The squares and streets were very fine and clean. Their palisade is in the best order and strength .... built in the same fashion as the one in which we were .... All their forts were alike .... some much larger than others (Will and Spinden, 1906:103-4).

Maximilian, a German count, traveled to the Mandan nation in the early 1800s and his account of the villages
or forts is somewhat different. Here is his description of one of the larger villages below the Knife River.

The whole town, according to Maximilian, had a very small diameter. It was situated in an extensive plain on a bluff about forty or fifty feet high on the south bank of the Missouri. From a distance it looked like a mass of mole hills, with numbers of grass blades growing between, these were the scalp poles and effigies of the gods. The ground on which the village was located was chosen for defence, the bluff on the river side went down perpendicularly, and the village was on a point jutting out into the river so that only one side needed protection. Across this point was a palisade and inside this was a ditch, three to four feet deep according to Catlin. The palisade, he says, was of timbers eighteen feet high and one or more feet in diameter, set far enough apart to allow of shooting between. The warriors stayed in the ditch in defending the palisade. Concerning this palisade Henry and Maximilian both mention that it was in very poor repair indeed, but Henry adds that he was told it could be put in good condition very soon, every person in the village lending a hand. There is yet no mention of bastions and ramparts such as Verendrye refers to, but Maximilian (Schoolcraft, 1851-57:31) describes something similar. He says that at the corners of the palisade in four places were arcs or bastions, which formed an angle open toward the village, and said to have been built by the whites. These were intrenchments in the form of an arc, covered with a matting of willow and having loop holes. (Plates 8, 9, and 10)

On entering the village it seemed to be a mass of circular houses from forty to ninety feet in diameter, set down haphazard closely crowded together. The houses were of earth with a smooth coating of pounded clay on the top, where most of the inhabitants were usually stationed. Before each house was a scaffold, fronting the covered entrance. These scaffolds were six feet high, twenty feet long and ten broad (Henry, 1897:340) and were used for hanging up corn and meat to dry. They had a good floor, also, which was covered in the fall with drying beans. The staging for drying corn and meat was made as follows
(Ibid): posts were set up on the scaffolds themselves, across these rafters were laid, and upon these cross rafters or poles the corn, meat and sliced squashes were hung. Before almost every house were one or more poles about twenty feet high, to which images of the gods, or sacrifices to them were attached.

In the center of the village was a large open space of about four acres (Henry, 1897:338; Maximilian, 386; Catlin, 1894:88) and in the center of this was the "Ark of the First Man." This was in the shape of a hogshead, of planks and hoops (Catlin gives this as eight to ten feet high, Maximilian as four or five). It was open above, the planks were embedded in the ground, and the hoops were branches tied around to hold these together. The Mandans called this the Big Canoe (Catlin, 1894:88) and in it were some of their greatest medicines. This open space was the seat of all their festivals, dances and ceremonies, and here also they played their games of Chungkee or Skohpe. The
space was closely surrounded by houses placed at equal distances apart and all facing the center. The largest of these lodges on the south side of the area was the medicine lodge, and on a pole above this was a figure of skin, with a carved wooden head, which represented the Evil Spirit.

About one quarter of a mile or less to the south of the village was a race-course; a hundred or more scaffolds on which the dead were deposited; slides for their games were also made outside the palisades. The ground about the houses was honeycombed with pits and caches in which most of the food and many of the valuables of the inhabitants were stored. The house roofs formed a general repository where bull boats, buffalo skulls, pottery, sledges and people were scattered promiscuously over the rounded surface, around the edge of which Bradbury says they built a sort of low railing (Will and Spinden, 1906:104-6).

By the time white man invaded the Mandan life, the Mandan had developed an impressive agricultural base.

The land about the Mandan villages, smooth river bottoms and very fertile, was always extremely easy to work, and required but the crudest implements. Consequently the cultivation was fairly extensive. Maximilian says that each family cultivated three fields of four or five acres each, which were never fenced. The farms were shifted to a new place when the old area began to yield smaller crops. There seems to have been no attempt at fertilization, and it was hardly necessary in view of the great abundance of good land. Henry (Catlin, 1894:343) gives an animated picture of the Mandan farming operations:

"We passed extensive fields of corn, beans, squashes and sunflowers. Many women and children were already employed in clearing and hoeing their plantations. . . . On each side were pleasant cultivated spots some of which stretched up the rising ground on our left, whilst on our right they ran nearly to the Missouri."
The Mandans used to raise enormous quantities of produce from these crudely tilled plots, and the most of it was stored away in caches. Each of these caches would hold from twenty to forty bushels of corn and beans, and the number of them was very large. Maximilian says that there was often from five hundred to eight hundred bushels of corn, alone, in the village. In view of his other statements this seems a very moderate estimate. The supply was large enough so that it was not only eaten by the people, but in the winter was sometimes fed to the horses (Catlin, 1894:389). Lewis and Clarke speak several times of buying corn of the Indians in lots of thirty bushels or more.

The methods of cultivation among the Mandans, though crude, were still above the most primitive types of tilling. The work in the fields was begun in May. Little trenches were made in rows, the grain was put in these and covered. During the summer the soil about the plants was dug up from three to four times. The harvest usually came in October and for that work every member of the village lent a hand, this being one of the few times when the men took any part in the domestic work. Between the rows of corn, rows of sunflowers were usually planted. The only noticeable feature in this description is the fact that the garden plots were cultivated and cared for during the summer, when most of the semi-agricultural tribes lower down the Missouri were absent on long hunting excursions.

The latitude of the Mandan villages required very hardy and quick-ripening vegetables; and we find that the Mandans had perfected a number of plants suited to the cold and dry climate of the region. The crops were often poor because of drought or early frost, but they never failed entirely (Catlin, 1894:389). The main products were corn, beans, squashes, sunflowers and tobacco. These were all grown when Verendrye visited them, and were still grown at the time of Maximilian's visit. Corn, however, surpassed all the rest in importance. It was a small
variety, five or six feet high, but was not the common, mottled "Squaw corn" found in the region later. Maximilian enumerates seven distinct sorts, as follows:—white, yellow, red, spotted, black, sugar, yellow flint, and red and white striped. The sweet corn was cut in the milk, then dried on the scaffolds in the sun and kept in the caches. The other corn was not gathered till it was ripe; it was then shelled and also put in the caches. Corn was eaten as succotash with beans, boiled as hominy, ground up into coarse flour and made into cakes, and also as a sort of gruel and in several mixtures with wild fruit.

The beans, as to the cultivation of which there is little information were, nevertheless, of considerable importance. Maximilian (Catlin, 1894:392) gives a number of varieties of these also; there were white, black, red, and speckled beans. These were not gathered until ripe, and were then spread out on the flooring of the scaffolds to dry, after which they, too, were stored in the caches. The beans were used in about the same way as the corn, both of them being mixed in many dishes. There were five varieties of squash or pumpkin, yellow, black, striped, long, and thick skinned. These were usually cut up into thin slices, hung by cords from the scaffold rafters and dried in the sun. They, too, were then stored away for future use, to be boiled with beans and corn or separately, or eaten with some of the wild plums or choke-cherries.

The sunflowers, Maximilian says, seemed to differ little from those ordinarily cultivated in civilization. There were three kinds, red seed, black seed, and a small seeded sort. There is no account of the method of preparation, but Maximilian tells us that very good cakes were made from them. The Mandan tobacco, which was used also by the Hidatsa and Arikara, while belonging to the Nicotianas, was a small species. Verendrye says that the tobacco was put up in rolls, that they cut it green and used it, stalks and all; he said it was not good. Later authorities do not agree on its preparation, however, as both Maximilian and Henry say that it was cut ripe and ground up fine. It was usually smoked mixed with the bark of the so-called red-willow or Cornus. Henry says that the blossoms were used, and were dried on a piece of pottery before the fire. Lewis
and Clarke and Gass both mention this tobacco and agree with Verendrye that it was not good to those who were accustomed to European tobacco. The Mandans themselves soon discarded their own variety, raising only a little each year to use in ceremonials.

Although hardly coming under agriculture, still as a related matter, it might be well to mention the wild vegetables and fruits which were so much used by the Indians of the region. These were june-berries, chokecherries, wild plums, the feverole, and especially the pomme blanche or Indian turnip. The latter were something like artichokes, white ovate, one to three inches long, and about the size of a man’s finger. They were collected in large quantities and formed a very common food (Will and Spinden, 1906:117-20).

While agriculture was of great importance to the Mandan, hunting and fishing were also means of obtaining food and clothing.

The Mandans derived a living from agriculture and the hunt in about equal proportions. Their methods of hunting differed little from those of their neighbors. Game was in abundance and many animals besides the buffalo contributed to their sustenance. Among these were antelope, elk, deer, bighorn, and an occasional bear, besides beaver, rabbits, ducks and geese. Other animals were killed for their hides alone, as wolves, foxes, ermine and panther. Eagles and other birds of prey were hunted for their plumes (Will and Spinden, 1906:120).

Another feature of note was that the Mandan was a shrewd trader. In fact when the first white man visited the Mandan he found them in possession of objects made in Europe.

The Mandans were economically well off in the early eighteenth century not only because they had greatly expanded their horticulture in a favorable setting but because they had begun to use their garden surplus in trade with their nomadic neighbors. In the prehorse era, and for a time after
the horse appeared on the northern plains, the Mandans enjoyed an enviable geographic position as middlemen between groups with different types of products to exchange. From an early date they traded their corn, beans, squash, and sunflower seed for bison and antelope hides, dried meat and pemmican, and flour made from the prairie turnip. At second hand they received trade goods originating far from the upper Missouri, such as obsidian from the Yellowstone Park region, native copper from the Great Lakes area, and conch shells (or artifacts made from them) from the Gulf Coast. Later, with the advent of the horse among tribes to the south and west and of firearms among tribes to the northeast, the Mandans became involved in an even more complex web of trading activity. Well before any Mandan saw a white man, they were receiving—and presumably trading—European-made goods (Bruner, 1961:199-200; Lehmer, 1939:169; Wood, 1974:11).

The Mandans were located at the nexus of three trade routes. From the west the Crows brought goods they had obtained at the Shoshoni rendezvous in southwestern Wyoming, where the Shoshonies traded with the Nez Perces, Flatheads, and Utes. From the southwest, by way of the Kiowas, Comanches, and later the Cheyennes and Arapahoes, they received goods of Pueblo and Spanish origin. And from the Crees and Assiniboins in the northeast they obtained firearms when these began filtering in from the English and French settlements along the Atlantic coast. Since most of this trade was in relatively perishable goods, the archaeological record is meager, but there is no doubt that it went on, much to the benefit of the Mandan middlemen. It has been conjectured, on logical grounds, that such an exchange between semisedentary horticultural peoples and nomadic hunters had the effect of stimulating each group in its specialty. Unfortunately, as the competition for trade monopolies in European goods intensified, warfare increased on the Great Plains, and such security as the village peoples had enjoyed was jeopardized and finally shattered (Wood, 1967:18-19; Holder, 1955:6; Ewers, 1954:433-35).
Thus we find the Mandan in 1750 a well-established and flourishing people, doing well with the resources and adapting well to the climate in which they lived.

Mandan culture in 1750 was the result of five hundred years of adaptive response to the Missouri River Valley ecology, fusion with other earth lodge cultures of the Eastern Plains, contact with pre-horse nomads and internal adjustments to the new settlement pattern (Spicer, 1961:204).

THE NOMADIC INDIANS AND THE TIPI

While the Mandans were living permanently in their villages, other tribes of nomadic Indians kept moving by, chasing food or being chased by other people.

The Mandans appear to have settled on the Plains long before the rest, and were already established there when La Verendrye reached their village in 1738. Most of the other tribes seem to have begun their migrations in the seventeenth or eighteenth century. The Plains Cree moved from their home far north of the Great Lakes in 1650 and were well established on the Plains by 1820. The Blackfeet, with their cognate tribes, Bloods and Piegans, leaving the present Plains Cree country, moved southwest into their historic location about the same time. The Assiniboines shifted from their country northwest of Lake Superior in Minnesota in the late 1600's, swinging north through Canada about 1775, then west and southwest to straddle the boundary between North Dakota and Canada by 1820. The Atsinas or Gros Ventres of the Prairie moved about the same time and were found in 1750 in eastern North Dakota and Minnesota, from which they arrived in northeastern Montana in 1820. The Crows, leaving their Hidatsa relatives on the Missouri in North Dakota, arrived in southern Montana and northern Wyoming about the middle of the eighteenth century.

The Sioux, found in the late eighteenth century near Duluth, moved southwest into Minnesota
and then on west into the Plains in the 1700's. Some of them reached the Black Hills in 1775. The Arapahoes in Minnesota moved to eastern North Dakota in 1670, where they parted with their kin, the Gros Ventres of the Prairie (Atsinas), afterward angling southwest across the northwest corner of South Dakota and eastern Wyoming, arriving in Colorado about 1800. Their allies, the Cheyennes, reaching central Minnesota in the mid-seventeenth century, moved through southern North Dakota in 1720 to 1780 and through southwestern South Dakota to south central Colorado in 1820. The Kiowas and Kiowa-Apaches moved from western Montana to southeastern Wyoming about 1805, and on to Oklahoma and the Texas Panhandle about 1830. The Comanches in 1700 shifted from southeastern Wyoming, across eastern Colorado about 1750, settling in the Texas Panhandle and below in 1800.

From these known migrations, it is obvious that there were many contacts between these tribes in the course of their wanderings, so that it is difficult to determine or even guess intelligently as to who taught whom to make and use the tipi. The known variations of detail in tipi structure and furnishings are so many and so diverse that even those tribes whose tipis are most similar are not always allied or cognate tribes or of the same linguistic stock.

It is now too late to learn much of the structure of the conical bark lodges used by these tribes in the woodlands from which they came, and to find out whether they had a three-pole or four-pole foundation and so used it in building their tents, or whether they may have taken over a new method from the first tipi-dwellers they met. It should not be forgotten that sedentary tribes like the Mandans may have used tipis on seasonal hunts into the plains long before there were any tribes living on the plains in skin tents.

Also, the first tipis used by newcomers to the plains may have been obtained through purchase, through capture, or as gifts. Or they may have learned from some captive woman of a tipi-dwelling tribe.

Moreover, where we find tipis of two tribes almost identical in structure and decoration (as with the Cheyennes and Arapahoes), this may be due merely to long association, even though originally each tribe learned its craft from some other.
George Bird Grinnell believed, although he gives no reasons for his faith, that the widespread use of the tipi did not long precede the coming of the horse to the plains, since in fact even as late as 1850 not half the Cheyennes were using tipis (Vestal, 1980:11-12).

Once horses were plentiful on the Plains and in the adjacent mountain regions, the tipi spread to the Dakotas east of the Missouri River and west to the Utes, Flatheads, Nez Percés, Cayuses, Umatillas, and Kootenais. We know that the Nez Percés obtained their tipis from the Crows. In like manner, the tipi spread north to the Stoney's and the Crees. There it came so late that the Indians never used the travois, preferring a cart.

Thus, it appears that the tipi became larger after horses were available to transport it, and that it spread rapidly among the marginal tribes who wished to share in the prosperity of the buffalo hunters.

With the destruction of the buffalo and the substitution of canvas for hides, the tipi remained much the same. But, since canvas will not hold when stakes are driven through it and will ravel out if cut into fringes, peg loops were introduced, and the pattern of the smoke flaps became trimmer and more standardized. Also, the light weight of canvas, as compared with tanned hides, encouraged Indians to make larger tents—twenty, twenty-five, or even thirty feet in diameter.

The tipi went out of common use on the Plains during the first decades of the present century. But today Indians, encouraged by popular interest, pitch and occupy tipis every summer wherever they gather sociably together for sports, ceremonies and dances or just for old times' sake (Vestal, 1980:13).

In our experience with tents they seem to be less than ideal as a place to live; yet the Indian tipi, made at first of buffalo hides and later of lightweight canvas, defies our beliefs and seems to have provided comfortable places in which to live.
No dwelling in all the world stirs the imagination like the tipi of the Plains Indian. It is without doubt one of the most picturesque of all shelters and one of the most practical movable dwellings ever invented. Comfortable, roomy, and well ventilated, it was ideal for the roving life these people led in following the buffalo herds up and down the country. It also proved to be just as ideal in a more permanent camp during the long winters on the prairies.

One need not to be an artist to appreciate its beauty of form and line, and no camper who has ever used a tipi would credit any other tent with such comfort and utility. Warm in winter, cool in summer, easy to pitch, and because of its conical shape, able to withstand terrific winds or driving rain, the tipi is a shelter that should appeal to every outdoorsman. It is not only an all-weather tent but a home as well (Laubin and Laubin, 1980:15).

Tipis of different tribes had small features which would vary. One of these was in the base structure of the tipi.

Differences in the outward appearance of various tribal styles of tipis are due primarily to the arrangement of the poles, since this determines the cut of the hide or canvas cover. Generally speaking, all the tribes about whom we have reliable information used tipis employing one of two possible types of pole arrangement. One of these types has a foundation of three poles, a tripod; the other has a foundation of four poles. This structural difference determines certain features that distinguish the two types (Laubin and Laubin, 1980:16). (Plate 11)

A tipi was, of course, lived in in the winter and cooked in also. Since a fire creates smoke, there must be provision for its elimination.

The open fire in the center of the tipi is its principal attribute, and, of course, the smoke vent should be above this central fire. If the tipi were a true cone, this vent or smoke hole would center around the crossing of the poles at the apex. Such a vent, to be practical, would have to be so
Fig. 3a, b, c, d, and e. Erecting the Sioux Tipi.

Plate 11

an alternate way
large that it could never be closed in wet weather. The Indians solved this problem by tilting the cone and extending the smoke hole down the long side, the front of the tent. The crossing of the poles is thus at the top end of the smoke hole instead of in the middle, so that it is possible to close the hole entirely by means of the projecting flaps or ears. But this also means that the poles must be arranged neatly and compactly. A haphazard arrangement would result in such a bulky mass of poles that they would choke the smoke hole and make it impossible to fit the cover smoothly or close the hole (Laubin and Laubin, 1980:16).

Tipis were of different sizes, according to their use and the needs of the users. The size also depended upon the availability of the materials needed to make them.

The length of the poles you are able to obtain and the traveling you intend to do will determine the size of your tipi. Indians used small lodges, about 12 feet in diameter, for hunting expeditions when they wished to travel fast and with little equipment. Chief One Bull had one of these small lodges of buffalo skin until 1936, when he sold it to a collector. Such a lodge requires poles only about 15 feet long.

In recent times the average family lodge has been from 18 to 20 feet in diameter, requiring poles 21 to 25 feet long. This is a good size if ease of moving the tipi is not too important and if more room is desired.

For a permanent camp there is much satisfaction in owning a lodge of from 23 to 30 feet in diameter, but such a tipi needs poles 27 to 40 feet long and is impractical for any other kind of use (Laubin and Laubin, 1980:19).

Plate 12 (Figure 1) shows the pattern used for the cover with sizes given which make it of about average size for buffalo hide tipis. Flat seams should be sewn with the canvas strips laid like shingles so the rain runs
off instead of into them. According to some stories I have read, Sioux tipis tilted more than Cheyennes as this allowed them to have a better smoke hole.

It has been said that the Sioux formerly tilted the cone of their tipis more than did the Cheyennes, but we have not been able to verify this from the few tipis still to be seen, or even to be sure of it from old photographs. Such a tipi would not be as graceful in appearance as one made from the pattern given here, but if you prefer a more tilted cone, set the radius point farther out from the edge and shorten the gores for the smoke flaps (Laubin and Laubin, 1980:27-28). (Plate 12)

The Sioux also thought themselves smarter than other tribes because of their use of the "ozan."

... which is an inside rain cover. This was used to some extent in early days, but few living Indians have ever seen one. The ozan amounted to another tent within the tipi and actually was an extension of the lining, with extra curtains which could be either tied, like an awning, overhead, or dropped in front of the bed, making a sort of private compartment, somewhat like a Pullman berth. We have designed it as separate from the lining, so that it need not be in use at all times, but it is a help in a hard, lasting rain, and increases warmth in cold weather, as we discovered (Laubin and Labuin, 1980:61).

See Plate 13 (Figure 6).

The lining as shown in Plate 13 (Figure 6) was tied to the inside of the tipi poles and was folded in at the bottom. This prevented drafts and dampness inside the tipi.

The lining, besides keeping away drafts and dampness, prevented rain from dripping off the poles and served a number of other purposes. It gave increased ventilation, helping to clear the
Fig. 1. Pattern for Sioux Tipi (18-foot).

Plate 12
atmosphere of smoke. The warm air rising inside the tipi drew in cold air from the outside, which came in under the cover and went up behind the lining, creating a perfect draft for the fire and taking the smoke out with it. Someone once said that the Indian lived in his chimney, which is literally correct, but in effect not true if a lining was used and the fire handled properly. The air space behind the lining also served as insulation, which helped to keep the tipi warm in winter and cool in summer.

War records and personal experiences were painted on the lining, so that it served another purpose, that of decoration, and it became as important to the appearance of a lodge as wall paper is to the average home (Laubin and Laubin, 1980:55-56).

Anyone who has camped in an ordinary tent knows how wet and damp everything is in the morning after a cool night—almost as wet as if he had camped out under the stars and the dew had settled directly on him. The same is true in a tipi without a lining, but all is different with one. With a lining a tipi is almost as dry as a house—drier than most summer cottages. The lining keeps the dew from condensing inside, and so is often spoken of as a dew cloth.

The lining also prevents the casting of shadows from the fire onto the outer wall, so is sometimes referred to as a "ghost screen." This was important to the Indians, as a matter not only of family privacy but of safety. No lurking enemy could see a shadow at which he could aim and so injure some occupant (Laubin and Laubin, 1980:56).

The base of the lining is usually tied as near to the ground as possible and to the butts of the poles. The tying cords are attached with little pebbles in the same way that the peg loops were attached to the cover. They are attached about eight inches from the bottom leaving a lower edge to be turned under so that ground cloths can be laid over it, sealing the interior completely from drafts and dust (Laubin and Labuin, 1980:60).

The origination of tipis was a direct result of the climate they were used in.
Faced east, the tipi receives the morning sun and has its back to the prevailing high winds. East of the Rocky Mountains the prevailing winds are westerly, and it is very unusual to have a due-east wind. The smoke flaps can be adjusted to shield against the wind from all other directions and are handled much as a man uses the lapels of his overcoat. If the wind is driving on his left cheek, he raises the left lapel against his face; if on the right cheek, the right lapel. In other words, the flaps are set as nearly down wind as possible, or quartering down in such a way as to block the wind from blowing down the smoke hole . . . . As an exception to the rule of facing east, the Assiniboines face their tipis south, but they live to the north, where prevailing storms come from the north (Laubin and Laubin, 1980:135). (Plate 14)

Due to the nature of the shelter provided by the tipi, it is a good place to live in any time of year. However, part of the comfort is due to the discomfort of the work required to keep it at its optimum.

It is the best possible outdoor shelter, whether the temperature is above sweltering or below freezing. When it is just ordinarily hot, the lining acts as enough of an insulator to keep it quite comfortable. When the weather is extremely hot, the cover and the lining can both be raised three or four feet on the sides and propped up on forked sticks. The tipi then is like a huge umbrella, with the extra ventilation of the smoke hole at the top. In such weather the cooking is done outside.

If the days are hot but the wind is too strong to make it practical to raise the cover, except perhaps for a few inches on the lee side, willow, cottonwood, or pine boughs may be leaned against the tipi on the south or west to break the heat. Sometimes an extra tarpaulin is stretched against the outside of the tipi to add more insulation. We have seen both done together—the boughs leaning against the tipi on top of the tarpaulin. Sometimes the tarpaulin is placed inside, between the cover and the poles, instead of in front of the poles.
Fig. 4. Parts of the Sioux Tipi.
like the lining. The purpose of any of these devices, of course, is to increase insulation and help keep out the heat (Laubin and Laubin, 1980:174-5).

And during storms when the wind changed, some Indians had ways of preventing discomfort to themselves.

The Hidatsas used tipi's only for summer, probably rather small ones, and, according to Wilson, when they were bothered by a change of wind, they merely turned the whole tipi around. This was accomplished by five to seven people. Entering the tipi after loosing the cover from the pegs outside, four persons took a foundation pole each and one the lifting pole, and swung the tipi to its new position. Then the loose poles were moved around where they belonged. The work of more than five people made it possible to move some of these other poles at the same time (Laubin and Laubin, 1980:177).

For winter along with proper location to avoid the weather extremes, the Indians also insulated their tipi's.

Winter camp sites were selected for as much shelter as possible, usually in the timber along a river bottom. Indians often made a windbreak of poles and brush, 10 to 12 feet high, around the tipi in winter. In the South they made a circle of posts filled in with dried, upright sunflower or ragweed stalks, bound securely with horizontal withes.

The old Blackfoot, Rides-to-the-Door, told us that sometimes, for extra sturdiness when in a permanent camp, slim willows were bound to the poles inside the tipi, all the way around at a height of five or six feet, or just under the height of the lining. This had the effect of bracing the poles with a huge hoop. Roan Bear, a ninety-seven-year-old Sioux, told us the same thing.

Sioux Indians also braced the poles from the inside in a severe wind with long, forked branches of box elder. The forks were cut short, so as not to puncture the cover, placed against the poles above the lining, and the long branch set into the ground at an angle.
For winter use, the lining was usually hung nearly straight up and down, reducing the area of the interior of the lodge but making heating easier. When hung in this way, it was, of course, fastened to pegs in the ground instead of to the butts of the poles. Old-timers have told us that in severe winter weather they sometimes used two linings, one tied to the bases of the poles and another inside almost perpendicular and pegged to the ground. The space between the cover and the outer lining was filled with prairie grass or hay. The space between the two linings was used for storage. It seems to us that it might be better to hang both linings together, nearly perpendicular, and stuff hay between them, but this is the way we were told it was done. The extra door flap, pictured on the lining pattern (Fig. 6) gave added protection during this kind of weather. When it was not needed, it was folded behind the lining so that it did not show. An ozan also added much to the comfort of the winter lodge (Laubin and Laubin, 1980:182).

We are convinced that Indians, in their buffalo-hide tipis, with plenty of warm furs and robes, were far more comfortable than the pioneers in their log cabins, heated with fire places only. The old-time tipi is a decided contrast, at least, to the way some of our Sioux friends spend the winter nowadays--40 degrees below zero in wall tents with only flattened corrugated cartons for flooring, stifling hot above, ice cold beneath, and no ventilation! (Laubin and Laubin, 1980:188).

From this description of the construction of and life in a tipi, it can be seen that siting and adjusting continuously were both necessary in order to live comfortably in such a shelter. Both of these features are still necessary if one wants to take maximum advantage of the climate in which one lives. (Plates 15, 16, and 17)
THE EARLY WHITE MAN

'Twas good to live when all the sod
Without no fence or fuss,
Belonged in partnership to God
The Gover'ment and us.
With skyline bounds from east to west
And room to go and come,
I loved my fellow man the best
When he was scattered some.

(Clark, 1922:92)
This was, and still is, a magnificent country, its broad expanses of brown prairie broken here and there by an isolated butte, a range of rugged, pine-topped hills, or rough breaks along the streams. Mountains, dark with pine, rose sharply from the plain. Etched deeply into the expanses of prairie were the valleys of the Missouri, the Yellowstone, and their tributaries. These were bordered here by areas of rugged badlands, grim and forbidding to the traveler but with a certain eerie beauty in the softly blended blues, grays, and yellowish-browns of the shales and sandstones. And where the dull red scoria occurred, it is not difficult to understand why General Sully remarked as he stood on the eastern escarpment of those badlands along the Little Missouri, "There is Hell with the fires out." It was a magnificent country, but now it is fenced and the romance and the wildlife that were once a part of it are gone. Only the prairies and the mountains and the memories remain.

Plains and mountains constituted only a part of the picture. There were streams of sweet, life-sustaining water, and sluggish streams and pools bitter and deadly with alkali. Winter's numbing cold threatened and took life, and so did the shimmering heat of summer. And the wind, unobstructed in its course, blew for days on end, an endless tugging at everything, movable and immovable. In the spring when there was rain, the prairies were green and the frogs croaked day and night, and even the barren badlands were decked with yellow daisies, deep mauve hyacinthine blossoms, the carmine of clustering vetches, and the white of Mariposa lilies; but for the rest of the year plant life was almost dormant. However, there was something more about the country than that which met the eye. The great spaces forced themselves upon those who traveled or lived on them, and sometimes demanded that they must be felt as well as seen. Perhaps it was the ease with which one could see great distances, perhaps it was the clear, blue sky overhead or the stars seemingly so close and large at night, perhaps it was the ceaseless wind, perhaps it was the mysterious blue haze on the distant hills—once thing was certain, once one had seen and felt this country, one never forgot.
Across this vast stage moved many colorful individuals to play their bits in a frontier drama which lasted for almost a century. These varied as to race, background, morals, and occupation but they all had one imagination-capturing quality--their daily lives were rarely characterized by colorless mediocrity. Some were good and some were bad, but those who were inefficient were not likely to be blessed with long life, for the frontier was no place for amateurs, honest or dishonest, moral or immoral. And fate, fickle as always, rewarded some with fame--sometimes earned, sometimes unearned--others with fleeting recognition that lasted for a generation, and many with a nameless and forgotten grave (Brown and Felton, 1955:13-15).
The first white men to move into the area of Eastern Montana were trappers, traders, and soldiers. One of the early forts, Fort Keogh, at what is now Miles City, is described as follows:

Fort Keogh--the hub of military activity in eastern Montana--had begun its existence in the fall of 1876 as the Tongue River Cantonment. The Cantonment, built in what is now the western edge of Miles City, consisted of crude "shelters made of logs placed on end in a trench dug in the soil and 'capped' with a 'plate' or log, on which rested a roof of poles and earth; not uncomfortable, as far as warmth was concerned, but terribly damp and leaky in the heavy rains of the spring" (Romeyn, 284). The following summer Fort Keogh was erected on the level prairie about two miles farther westward. This was a typical frontier post with a row of officers' quarters built in a semicircle around the western part of the parade ground, two-story barracks for the enlisted men--or swaddies as they were called in Milestown--a guardhouse, post trader's store, stables, officers' club, warehouses, and other miscellaneous buildings. Most of the buildings were of frame construction, but a few--including the studio Huffman occupied--were built of logs placed upright, stockade fashion (Brown and Felton, 1955:98).

Life in such marvelous works of architecture was not very pleasant as related by the wife of an Army captain.

Captain Baldwin's wife included in the memoirs of her husband some of her own intimate recollections of the post--how glad the wives were to move from the "vermin-infected, ramshackle huts" of the cantonment--how they had been busy for months before this move, preparing curtains of materials they salvaged in various places--and what life was like in their new homes at Fort Keogh. She related that in the new homes there were fireplaces for heating, in which cottonwood burned rapidly without giving off much heat,
and pine, if not sufficiently dry, charred to a dark mass that emitted little other than a shower of inefficient sparks; and she noted that the foundations were high and the winter winds sucked underneath, causing the carpets to billow up from the floor until a banking of horse manure and soil between the supports put an end to the discomfort (Brown and Felton, 1955:127-8).

In order to serve the soldiers, freighters (horse and oxen-drawn wagon trains) established routes or trails into the area. Settlers also began moving in as the soldiers moved the Indians to reservations or eliminated them entirely. This necessitated an establishment called a road house or road ranch. (Plates 18, 19, 20)

Although the railroad wiped out most of the picturesque features of frontier transportation, road ranches remained for many years scattered over the countryside. These were rough log shacks of one, two, and sometimes three rooms where travelers might find food and lodging for the night; and they were patronized by patrons of the stage and by settlers going to and from town. Food, though usually satisfying, was invariably plain, and sometimes cooked and served under conditions far from appetizing.

The most interesting feature of these places was the sleeping accommodations. The "bed room" was usually a room with a few bunks. If there were more customers than bunk space, the late-comers rolled out their bedrolls and slept on the floor. If the bed was a double one and the place filled to capacity, the single traveler would be expected to share it with another. When ladies were present, the problem was complicated for the facilities were designed to serve but a single sex. While en route to their ranch in April of 1883, the Aldersons stayed at a road ranch the first night out of Miles City. Mrs. Alderson remembered that they had a comfortable room to themselves with a good bed which the hostess must have given up since the ordinary accommodations consisted of a kind of bunk room which was occupied on this occasion by fully 15 men
(Alderson and Smith, 1942:25). As women travelers became more and more common, this sort of courtesy gave way to making simple provisions for such guests. This usually consisted of hanging a curtain around a bed to provide a bit of privacy. The men added the necessary bit of courtesy by retiring to another room or outside while the lady or ladies went to bed—this also being the usual procedure for a stranger at a settler's home.

Some of these road ranches were of the sort to be remembered. One of these was a rough cabin by the Musselshell River on the road between Jordan and Lewiston. When one visitor stopped overnight, the things which impressed him most were the thick layer of sand and dirt on the floor, the muslin covering of the wall—from which dust cascaded at the slightest touch—and a very dirty bed in which he felt it wise to sleep without undressing. The operator of this establishment, a
bewhiskered recluse named Mosby, had a government license for wholesale liquor sales. Allegedly, he was the son of J. S. Mosby, the famous raider of the Civil War who was exceedingly annoying to the troops of Major General Sheridan.

Another of these stopping places remembered by many who traveled to Miles City was "Piper Dan's." This road ranch, about 35 miles to the south on the road up the Tongue Valley, was a stop where the mail stage changed horses. Piper Dan, a tall, lean, bearded Scotsman who played bagpipes, was given this descriptive name to distinguish him from other Dans who had also seen fit to cloak themselves in anonymity. Mrs. Alderson, the first bride to stop at his place, remembered that

His place was clean enough, but rough and untidy, and the walls of his two-room log house was papered from end to end with the pink pages of Police Gazettes. I'd been warned I'd better not look at them, so of course, as soon as the men went out to put up the horses, look at the was the first thing I did. . . . (Brown and Felton, 1955:188-90).
This section is more personal for me as I was raised in a homestead shack and have experienced some of the less than pleasant features of "the good old days."

In the west end of Richland County is a place called Andes. It is no longer a community but the family who established it was that of Samuel and Florence Andes.

Samuel and Florence Andes and five children arrived in Culbertson on the train from Missouri in September, 1910. They were met in Culbertson by Frank McKnight with his team and wagon, who took them to Florence's sister's home south of the Missouri River. They stayed there until Sam, assisted by neighbors, built a sod house on the 320 acres he had filed on.

The next need was water, so Sam got out his "witching stick" and soon found a likely spot. With pick and shovel he was soon digging a well, assisted by Florence and the children. It took him some time before he got deep enough to strike water, but by continued hard work he finally saw water trickling in. The next morning there were several feet of water and they were happy. It was not good for drinking but served other purposes. They had located a vein of coal on the school section, so with a warm sod house, a well and coal they were ready for a long lonely winter on a homestead in Montana.

In the spring Sam built fences and using a team of oxen he put in his first crop, 20 acres of spring wheat. He soon acquired horses and machinery and through the 20 years they were in Montana he bought and used a steam engine, threshing machine, which was the first to have a grain header, a combine, telephone and light plant.

In the spring of 1912 came the influx of new homesteaders. In the meantime, Sam had built a sod blacksmith shop where evenings and
an alternate way

Present Montana County Boundaries (56 counties) (dates counties were created)
mornings he shod horses and sharpened ploughshares for all the homesteaders. Later, 1914 to be exact, the first post office was housed in the corner of this shop (Courage Enough, 1975:33).

In the meantime, five more children were born to this family. For Florence, school and learning were precious. She dreamed of college for her children and visioned the various fields of study they might enter. She taught them the value of education, a privilege and not a duty. And by hard work and much sacrifice this was accomplished. The children were all sent to college; two have doctor's degrees, three have master's degrees, one is a doctor of medicine, one a PHD in chemistry, one a college professor in Kansas University, one a Junior College teacher, one is a nurse with a B.S. Degree, one more is now completing a doctor's degree, one is a millionaire in construction and one was killed in World War II (Courage Enough, 1975:33).

Another settler in this Andes area was the Arthaud family. Robert Arthaud, who later became my grade school principal, was a very young boy at this time and therefore wrote the following from memory.

The John Arthaud family moved to the Mondak area in 1908, coming from North Dakota. Originally from Iowa, John Arthaud taught school for two years in Steele, North Dakota and then located on a homestead in the Big Opening area near the mouth of the Yellowstone River. There he built a house of cottonwood logs and remained for two years. Since there were no government dams regulating the flow of the river then, during the June rise of high water, his alfalfa crop was covered with river mud. He attempted to develop the homestead, but it was a losing battle with the river. So he taught the old Mann School near Dore to make a living those two years. He worked a team of horses on the main canal during one of those years when the project to irrigate the Lower Yellowstone Valley first came through. He had explored the dryland section about thirty miles west of Dore and in 1910 he took a homestead three miles southeast of the settlement of Andes.
The first year in the Andes country was a rugged one. I was then five years old. We lived in a tent most of the summer and between cutting the long prairie grass for hay for his horses and building another shack, it was a full and strenuous summer. My mother was staying at Dore to finish out Dad's second term of teaching the Mann School and then she joined us on the homestead. We moved the household goods to the new location in a hayrack. The house was built of cottonwood lumber and then in the fall we built a sod house by laying layers of cut prairie sod on the outside of the wooden frame.

The next summer our permanent farm home was built, together with a barn and granery, and later the house was enlarged. There we lived until my sister and I finished high school in Sidney, she in 1922, and I in 1923 (Courage Enough, 1975:35-6).

Both of these families were more "smart" than the average. A more typical example of a homesteader's shack and the environment is described by William Baue, Jr., as follows.

The shacks most of the homesteaders built were made of wood covered with tarpaper and were extremely uncomfortable and cold. They had no idea how cold it could get in Montana. Usually one door, one window, crude furniture made of scrap lumber, one stove that served as a heater and cook stove, made up the furnishings. Dad made soda biscuits every day, and ate lots of beans. He dug a hole in the ground under his bedroll and put his potatoes in it to keep them from freezing. His water would freeze solid every night.

One of the many things that plagued them was that they didn't have anything to do anything with. There wasn't so much as a stick of wood to prop open a door, no tin cans to dip anything with, not a piece of iron to make anything with. Just grass, hills, wind, and very little water. Imagine, if you can, not a tree or fence to tie a horse to. You either had to hobble a horse or keep riding until you found something to tie him to (Courage Enough, 1975:37-8).
Another neighbor of ours, John L. Benson, never built a house but lived his life in a dugout.

John L. Benson was one of the early pioneers of Richland County. He came to Montana in 1890 when he was about 16 years old. He worked on the Merrill ranch for several years and took as his pay six or eight mares. He then homesteaded 15 miles straight west of Fairview. He pitched a tent and lived in it for a couple of years until he made a home on a sidehill, which was partly a dugout with a log front. He lived in that all his life. He also built a barn and corrals all from logs. There was a spring nearby so he didn't have to dig a well. He raised horses and sold them, did some farming, and grew both prairie hay and alfalfa hay on a piece of irrigated land that he owned in the valley. This land is now the west end of the city of Sidney.

John never liked cows, but he got into the cattle business anyway. A neighbor owed him some money and he paid him a cow for the debt. From that cow he eventually got a big herd of cattle.

He owned the first car in our community, and oft times we kids would ride to his home with him and walk back to our house just so we could have a ride in his car. He also had the first radio. It had earphones and our young neighborhood boys would walk down to his place in the evenings, especially in the winter, to listen to the radio, taking turns using the earphones.

John enjoyed the boys very much and would think up things to entertain them. One thing he did was to fasten ropes to the logs in the ceiling, making a sort of trapeze. They would take turns and do tricks, with John right in the middle of it all. One time he climbed up there, forgetting he had his lit pipe in his mouth. As he was turning around up there, the hot ashes fell from his pipe and landed in his whiskers and hair. There wasn't much of a fire, but they all had a good laugh. Another thing John did was target-shoot in the house. The boys would pool their money, what little they had, and when Benson went to town he would buy a case of .22 shells. If there wasn't enough money from the boys, Benson would pay the difference. Then they would put a row of nails into a log, and the one who could drive in most nails was the winner (Courage Enough, 1975:41).
Another family whom I do not know actually built a sod apartment house.

We had enough room in the shack for the parents to sleep, as we didn't want them roughing it any more than necessary at their age. Even so, it was a tight squeeze. Don and Leila and Russ and I slept outdoors in bedrolls, but when it rained, three couples in that tiny shack was something to behold! Anyway we had fun about it all.

From this little shack we built a much larger frame house, but before it was finished, we had a big windstorm that blew it away. Next we decided to build a sod apartment house beside a small hill. It was a long one with room for us all and we lived there for some time. It had three bedrooms and a kitchen where we all ate together. Son Bill was born there (Courage Enough, 1975:649).

The following is written by Della Howard Lightner who moved with her family to Montana at the age of nine. I believe she lived on what we call "The Howard Farm" which we now own. You will note that life was not really pleasant.

Dad had looked around and found a piece of land he liked in the little valley across the river. They put some logs on it. In those days if you put some logs or something on a piece of land it was yours. The country wasn't surveyed at that time so you couldn't file on the land. Our homestead was on the south side of the Missouri River. In the summer of 1902 the surveyors came through. Someone built a land office where they started the town of Mondak. Sweetman and Stevens built a general store there. Somehow a depot and a post office materialized, also nine saloons. Before that, Dad would walk to Buford for the paper and the mail.

In September Dad built us a one-room log house. He made us a table. We used chunks of logs to sit on. He also made some benches and we used wooden boxes nailed to the wall for our cupboards. There was no place to get lumber so we had to live on dirt floors. We spread hay on the floors and
sewed gunny sacks together and put them on the hay for rugs. They were pegged down with wooden pegs. When they wore through we sewed another on top. That winter was really rough. Not being used to the cold, our clothes weren't warm enough. The temperature was 42 below and the snow got so deep it was hard to take.

Dad and the boys made a barn and corral for the horses. My twelve-year-old brother worked for Gilbertson and he gave him a range cow. She was wild but he and Mother tamed her down. In the winter she had a calf and they had to tie her hind legs to milk her. She finally became quite docile as she liked the potatoes, vegetables and bran that Mother fed her.

Mother and I cried a lot that first year, we were alone so much of the time. The men were all out working. In the spring Dad built another room. The men went to Williston, North Dakota and got some lumber. They bought tables, chairs, beds and other furniture. We made bed ticks and stuffed them with hay. When Dad built the extra room, it made an ell and that was my secret crying place until someone would find me. We didn't know what a lawn was in those days so the grass and weeds would grow up close to the house.

In January, 1905, the coldest time of the year, Dad rode horseback to Glendive, Montana to serve on the jury. In 1906 they started the big irrigation ditch. They were hampered in their work because it rained from April until July. It rained so hard it washed all the dirt off our roof. We slept under canvases and our oilcloth tablecloth until one neighbor who had a shingled roof took us in until we could get our roof fixed (Courage Enough, 1975:415).

(Plate 23 and 24)

In reading this part of the paper you have read about dryland farming; crops raised were oats, barley, corn, hay, wheat, and flax in good years and only thistles in dry years; and irrigated farms, where sugar beets, alfalfa hay, wheat, oats, barley, corn and beans were raised. Cattle, sheep, pigs, and fowl were kept to supply milk, meat, eggs, feather ticks, and as a cash crop. You might
Note that the ancient Indians were able to raise a larger variety of crops; and in spite of our university research centers, we still are behind them in that facet. In fairness, though, we get better production and are successful in farming the dryland areas which they could not do.

There were only trees along the river bottom and it was necessary to mine coal from small coal mines (we have some on "The Howard Farm"), in order to heat what shelters existed from the cold, cold winters and wind. I would like to make a comment on the fact that winters are much colder in Eastern Montana than people seem to believe or realize and that architects from Billings and Great Falls typically fail in their efforts at designing buildings which are adequate for the climate. Only this year it was necessary to install
larger heater elements in 72 electric furnaces in Crestwood Inn as the ones furnished the contractor as designed by the architect were inadequate. Water lines also froze two or three times in the ceiling, and this was one of the warmest winters on record. The people of Eastern Montana have come to expect this from architects and have, understandably, very little use for them.
The Foreword of the book *Courage Enough* is a nice tribute to the people and this area from which I come. I wish for you to read it.

This book sets down the personal stories of the courageous families and individuals who were in fact the very last in the nation to settle under the Homestead Act. And in the telling we find this spot in Eastern Montana and Western North Dakota to be where the last of the Indians surrendered and the last of the buffalo were hunted. TV circuits have just recently been available and the Squaw Gap area was the last in the nation to put in a telephone line. The stories told within the pages of this book are of those people who in their lifetime, saw changes in their life style greater than any other generation. . . many lived from the horse and buggy days to jet plane travel and to see a man step onto the moon. The great thing about them was that they helped promote, lived with and moved on to the next phase of progress with equal spirit, never daunted and seemingly enjoyed each step of the way. Some of them moved away to other areas, some have died. Now, as circumstances have a way of doing, they have come full turn and with the depleted natural resources, the nation turns it's attention again to this area as a last resort, for the rich deposits it holds of oil and coal (*Courage Enough* 1975:III).
THESIS OBJECTIVE

Using Hay Creek Farms, Inc., as a study model, I want to compare our farming, energy use, production, and life systems with those I have written about and those I can foresee as a possible alternative to our present system so that our production can increase while also increasing the fertility of our soil, using less unrenewable energy, saving time in relation to units of production and improving the lifestyle of those people operating the farm.
HAY CREEK FARMS, INC.

Hay Creek Farms, Inc., presently operates 1,791 acres of land in northeastern Montana. The land is spread out in small pieces with a distance of 11½ miles from the present farmstead to the proposed farmstead. The proposed farmstead is actually at the site of the original homestead and, therefore, has existing buildings, some of which can be used, some only as salvageable material.

Of this 1,791 acres, 1,705 are in use for production of agriculture products (animal and crop). Of this 1,705 acres, 788 acres are or have been in crop production and 917 acres are usable only for grazing. So, without animal agriculture the production from those 917 acres would be lost to human use. Fifty-four acres are in drain ditches and other non production uses and 32 acres are in farmsteads.

In 1972 we asked the United States Department of Agriculture, Soil Conservation Service, to prepare a soil and water conservation plan for the farm. I have used the data they collected and produced as a base for production figures and present production capabilities.

We have altered our production since 1972 from crops as a major source of income to animals as a major source of income (animal agriculture has been proven
to be more profitable over the life of a farm operation than has crop agriculture although it is more labor intensive). This necessitated planting most of our crop land to hay (alfalfa) and increasing the size of our cattle herd. Planting fields into permanent plant stands is a very good way to prevent wind and water-caused soil erosion and since alfalfa is a legume it also adds nitrogen to the soil. This enhances the soil value by increasing fertility and saving the soil itself for future generations.

It is also worthy of note that more digestible protein for human consumption can be produced per acre through animal and crop agriculture than through crop production alone, and in our case, I would like to again mention that we would also lose the production of 917 acres without animal agriculture.

As our farm is not very large it is necessary to produce those products which have a higher profit potential than the average for our area so we produce Registered Black Angus to be used as breeding stock. We have been successful in this enterprise in terms of our ability to raise those kinds of animals that excel in production per pound of feed but have not been as successful at marketing them as we would wish. Due to this, any form of cost savings which could be achieved in the operation of the farm is very welcome. Also any
method of drawing attention to the farm as a leader in agriculture would help to market the cattle and provide a higher profit level.

One of the deficiencies of the Great Plains area is water in the form of rainfall; it varies from 8 inches to 19 inches per year at our place. Because of this it becomes difficult to achieve uniform levels of production. In good years crops are good; grazing is abundant; and life flourishes. In bad years, nothing grows; people give up their land; and life practically vanishes. The best way to stabilize this situation is to irrigate. For this reason, we bought an irrigated farm in 1967. This farm is a long way from our other property and since 1967 we have found ourselves using as much time and energy just getting from one place to another as we use working. In order to improve on this condition, we have been looking at different ways to provide ourselves security from drought and also save time and energy. One such way appears to be to irrigate some of the dryland farm. My site plans show the location of the land we feel best for this purpose. We actually believe we could sell the land below the irrigation canal and farm only 1,631 acres with an overall increase in production by irrigating the dryland area shown. Besides saving travel time and money, we would use automatic irrigation equipment, saving labor and laborers' time. We would irrigate 160
acres instead of 107 and the land to be irrigated is much more productive per acre, due to soil type, than that which we presently irrigate, therefore higher overall production. (Plates 27, 28 and 29)

The soil types of the present irrigated land are silty clay, clay, and saline. These are very hard when dry and while they hold a lot of water, they do not allow the crops to use it well (see Figure 1, Plate 30). The soil types of the proposed irrigation area are clay loam (340 B and C, Plate 31) and sandy loam (140 C and D, Plate 31). Both are much easier to work, hold more air and allow plants to take up water easier for faster growth. Under the surface is a layer of clay to silty clay.

As shown in Figure 1 [Plate 30] below, the water content at FC and PWP both increase as the percentage of fine particles in the soil increases. The amount of water held between FC and PWP, which equals AWC, increases as there are more fine particles, up to a point, after which it declines. This is because clay particles hold soil water more tightly than do sand and silt particles. Consequently, in soils with predominantly clay particles, a greater percentage of the total water held is unavailable to plants (Christensen and Westesen, 1976).

Within a textural class, AWC generally increases with more soil organic matter. Soil organic matter exerts this influence largely through its effect on soil structure. Soil structure can be defined as the arrangement of soil particles into crumbs or aggregates. Soils which are well aggregated generally have soil air-water relationships favorable for crop growth (Christensen and Westesen, 1976).

The water holding capacity of this soil for alfalfa is 6.7 inches, corn and grain 5.2 inches.
and grass 3.7 inches. The crops we grow can generally use 50 percent of this available moisture without stress. These crops also use the moisture at a rate of .23 to .28 inches per day. Thus alfalfa can use 6.7 inches + 2 or 3.35 inches at a rate of .28 inches per day and therefore requires 3.35 inches of moisture through rain or irrigation each 12 days. Corn and grain uses 5.2 inches + 2 at .23 inches per day and needs 2.6 inches each day 11 1/2 days while grass needs 3.7 inches + 2 at .23 inches per day and needs 1.85 inches of moisture each 8 days. These are calculated using our known soil types (Plate 31),
expected active root zones of our crops (Plate 32) and the irrigation climatic area number for our farm (Plate 33).

The active root zone of a crop depends not only on the soil, but also upon the crop and its stage of growth. To accurately estimate the total AWC of a soil for a particular crop, knowledge of rooting depth is essential. Table 2 gives the depths of the active root zones for the major

Plate 31
irrigated crops grown in Montana. When soil properties do not limit root growth, the information in Table 2 can be used in conjunction with the information in Table 1, to estimate total AWC.

Root distribution and water use from the active root zone of a crop is not uniform in depth, as illustrated in Figure 2 below. Note that about 70% of the crop's water requirement is taken up from the upper one-half of the root zone.

Plate 32

Table 2. Active root zone of crops under irrigation.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Active Root Zone in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>5</td>
</tr>
<tr>
<td>Small grains, Field corn, Sugar beets</td>
<td>4</td>
</tr>
<tr>
<td>Dry beans, Grass pasture, Sweet corn</td>
<td>3</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2</td>
</tr>
</tbody>
</table>

(Christensen and Westesen, 1976)
an alternate way
In our search for efficiency we use the results of Montana State University's Agricultural Research Center and other research centers to help us to plant the proper varieties of crops so as to get the most production per unit of input. Our cattle are bred for efficiency and those which are least efficient are continually culled out and sold. We even buy tractors based on results of University of Nebraska tractor tests and in this continuing effort to be more efficient I want to look at some of the irrigation systems available in order to make an attempt at picking that system most efficient for our use.
IRRIGATION SYSTEMS

Requirements of the system:

1. must work on slopes up to 12%,
2. must not require high energy inputs,
3. must not cause soil erosion,
4. must not lose large amounts of water to evaporation,
5. must be able to be used with pasture rotation grazing systems and crop rotation, and meet the needs of varying crops for different amounts of moisture.

I. Big squirts. Big squirts or travelers are giant versions of traveling lawn sprinklers which follow the garden hose. Big squirts run on about 130#/s.in. pressure and can irrigate a path 150 feet on either side of it or a 300 foot wide path overall. They require a
hose or an open ditch to follow for a water source. They generally have the pump system mounted on the traveling gun. They could use hose and underground pipe or combinations of such for their source water. Because of the need to spray such large distances they require very high pressures and also lose a high percentage (up to 35%) into the air.

II. Gated pipe. Gated pipe requires the least pressure, loses the least water to evaporation, and is also the cheapest system to buy; but in order to use it, you must irrigate in ditch or by flood and gravity. This is the most highly labor-intensive system and can also be highly soil erosive. It also requires more water in order to irrigate a crop, which could make it totally impractical for us as we have only a limited amount of water.
III. High and low pressure systems. Systems using high pressure, spray upward and cover a strip about 100 to 125 feet in width for a period of 30 to 45 minutes. These systems require water pressures of 80#/s.in. or more. Systems using low pressure run 10 to 25#/s.in. and spray an area of 10 feet for 10 to 15 minutes. They spray downward and less water is lost to evaporation and there is less pattern variation due to wind drift. In tests involving high pressure, low pressure and furrow irrigation, high pressure irrigation required 68.7 percent of the total energy required to produce a crop, while for low pressure and furrow systems the energy requirements were 63.2 percent and 62.3 percent respectively (Blair, 1980:96). The following systems can be either high or low pressure.
IV. Center pivot systems. Center pivot systems in general are built of a large pipe approximately ¼ mile long suspended between motorized towers. One end is hooked to the source of water at the center of the field and the rest of the system rotates around that point spraying water to irrigate a crop. There are several systems developed to irrigate the corners of the fields left unirrigated by the rotating center pivot system. One is a big sprinkler head which sprays from the end of the center pivot system. This requires high pressure and the entire system shuts off in order to allow the end gun to operate. Another system has buried pipe in each corner of the field and the center pivot stops at an inlet, is hooked up and through the corner irrigates while the rest of the system sits and waits. This requires extra time and labor. With high pressure, fewer pipes are required underground than with low pressure for this system. Another corner system is the Valley corner system. This system uses a trailing pipe which pivots off the main pipe as it gets to corners. The trailing leg is computer controlled and can irrigate any shaped area that it can reach outside of the circle irrigated by the center pivot. Most of these systems require about 1,000 G.P.M. of water.
V. Linear and automatic wheel roll systems. Linear systems are basically center pivots without fixed ends. They require an open ditch or a buried pipe and a flexible hose for a water source. Automatic wheel roll systems are basically linear systems which are mounted on large wheels which carry the system across the field. They are usually high pressure and cannot be used on tall crops as the pipe is only 3 or 4 feet above the ground.
Of these different systems the most attractive to me is the low pressure linear system using buried pipe and flexible hose as a water source. This system allows you to have square fields for ease of machine operation, easy fencing, easy pasture or crop rotation with flexibility of water use and allows you to raise tall crops as well as pasture and reach all the corners with water. It also has low labor requirements.

The problem with this system for our site is its requirement of a buried pipe and flexible hose for water delivery from the dam to the sprinkler. Because of the water friction which must be overcome through this pipe and hose, the linear system would require at least 25 percent more energy to run it than a center pivot with trailing corner system. Therefore, a center pivot system could save energy; it is possible that it could save labor over the lineal system; it would irrigate the same number of acres, but it is harder to farm with and crop rotation is more complex.

Due largely to the 25 percent energy saving of the center pivot with corner system and in spite of its more difficult pattern to farm, I have decided to use the Valley corner system with a center pivot for our farm.
Energy Use by the Irrigation System

The irrigation system requires a maximum head pressure of 168 feet of water and a minimum head of 118 feet of water. This takes care of pipe friction, water delivery, and provides 10 p.s.i. of water pressure at the nozzles. The volume of water pumped is 1,000 G.P.M. and the system is 80 percent efficient; therefore, only 800 G.P.M. actually are delivered to the ground.

A head of 168 feet for this system requires 53 H.P. to pump 1,000 G.P.M. This equals 39.5 K.W. A head of 118 feet requires 37 H.P. to pump 1,000 G.P.M. This equals 27.6 K.W. The average power needed for our field is 41.25 H.P. or 30.75 K.W. Besides the pump, the towers need 6 K.W. to move the system. Thus, the maximum power required is 45.5 K.W.; the minimum power required is 33.6 K.W.; and the average power required is 36.75 K.W. The average power required is not half the difference of the maximum and minimum because of the fact much more of the field can be irrigated at minimum power than requires maximum power.

The dam is designed to hold 160 acre feet of water which is the same as 160 acres covered by 1 foot of water. The dam is also continually being filled by flowing wells, run off from the sprinkler, and some rains. Due to this 200 acre feet of water is considered to be the amount of available supply.
By calculating the needs of different crops (Plate 34) versus the available water supply, it is possible to figure a balancing acreage. For this thesis, 64 acres of alfalfa-grass mixture, 50 acres of small grains, and 46 acres of corn silage will provide that balance.

By going to Plate 34, you can then calculate when the system must run and how often. The time the system must run for the year is 1,375 hours, which on an average year with the crop mix given would provide each crop its recommended moisture and use up the available water supply. From Plate 34 it can be seen that some months the system must operate more than others. This system will provide all the water required in the driest month operating 86 percent of the time; therefore, it is adequate. Also from Plate 34 it can be seen that some months are drier than normal. However, from the climatological data the driest month on record (one month) and the wettest (another) sometimes fall on the same year and therefore the overall moisture is closer to average than either the maximum or minimum lines indicate.

The maximum amount of K.W.H.s used by the system in any one month is 23,520. The system would use 50,531 K.W.H.s each season.
This chart uses data for Montana Irrigation Climatic Area No. 2

Williston, N.D. Climatological Data

Plate 34
FEEDING SYSTEMS

The type of feedlot used is a very important consideration in the overall farm operation. Feedlots range all the way from air-conditioned or heated barns with slotted floors and manure pits hooked to methane conversion systems, to open pastures with feed fed on the ground in different locations daily.

In the past several years I have studied these different systems carefully and would like to briefly describe several feedlot types and then explain my choice of feedlot type for the farm.

I. Open lot with mounds, slatted windbreaks, fenceline feeding, and 250 square feet per animal minimum. This type of feeding system has the lowest initial capital investment per head. This system works well for those who want to background cattle outside and move them into
a confinement barn. It also fits the needs of a small one-lot full per year feeder. (This is our present feeding method.) Run-off controls must be designed and the value of recoverable manure will be $7-$8 per head less than from a slatted-confinement facility. You also use more feed per pound of gain and get lower gain rates in the open lot versus a confinement system. To make this system work at its best, bedding must be provided for the animals, slatted windbreaks should be at right angles to the prevailing wind, and mounds should be high enough to stay dry. There must be at least 8 inch per head of capacity of feed bunk for a full-feed system and 2 feet for a clean-up feeding system (Successful Farming, 1980:B2).

II. Manure pack with scrape alley. This is a good system for cattle feeders finishing out a small number of animals, and it works well with
backgrounding. The investment is much lower than a slotted-floor confinement barn but labor and machinery costs for cleaning the lot soon eat up the difference if many cattle are being fed. This lot is basically a confinement system with the animals under roof in a building open to the south. This protects them from the elements and keeps them dry. Two or three pounds of bedding per day in an area of 17 to 20 square feet per head are required. The manure from this system is generally worth five dollars per head per day less than a slotted-confinement system (Successful Farming, 1980:B-2).

III. Conventional feedlot. A conventional feedlot with a concrete floor fenceline feed bunk and 17 to 20 square feet per head of space does a good job for feeders feeding only one lotful per year. It is the second cheapest system of the five we are looking at. This
system requires two to three pounds of bedding per head per day, and, again, is a high labor system requiring scraping and run-off control. The manure will be worth four dollars per head per year less than that from a slotted floor confinement system (Successful Farming, 1980:B-4).

IV. Cold slotted-floor confinement barn. This is a system where the animals are confined in a south facing, open sided building with slotted floors which allow the manure to be pushed through by the movement of the animals. There must be a pit or lagoon to hold the manure and the feeding can be automatic or in a fenceline bunk. This system requires 15-18 square feet per head of area but no bedding and labor costs are low as cleaning or pumping is required only once or twice a year. The manure is worth $12 per
animal per feeding period. The major disadvantage is the high initial capital costs (Successful Farming, 1980:B-4).

V. Warm slotted-floor confinement barn. This system parallels the cold slotted floor confinement barn in almost every way. The difference between them is that the warm system is entirely enclosed and the environment is therefore totally controlled. The cost is very high per animal and gain rates, feed efficiency, and manure recovery are not enough better, if better at all, than other systems to merit its use. The only way it might be feasible for cattle is if it were connected to a methane generator (Successful Farming, 1980:B-4).
The system I feel is best for us must fit the following:

1. We use it for one feeding cycle per year.
2. We have at most 150 head of calves at one time.
3. Our climate dictates a system that does not have to be cleaned if freezing weather makes it too difficult.
4. Our climate dictates some form of protection for the animals.

Due to the above requirements, it seems that an open sided shed with a protected feed bunk system inside it along with a mound system and slatted fence are merited in our climate and valid for our feeding requirements. With this system we would like to allow 20 square feet per head of cover and bedded area and at least 250 square feet per head of mounded, slatted-fence wind-protected, outdoor area. This is a combination of the open lot with mounds and the manure pack systems. This should give protection to the animals, allowing for good feed efficiency and rates of gain, while allowing them enough area to be able to keep clean and in condition for breeding which is what we feed for. The shed would also provide room for machinery storage in the feeding alley, particularly the feeder mixer and loader.
The study of energy systems is essential to this project of a coordinated farming and living system.

In a relatively minute segment of history, the economic and social structure of the United States, and to a major degree the entire world, has come to be highly dependent upon exploited residual resources. This dependency and exploitation is increasing at the same time these residual resources are limited.

Central in the crisis of escalating exploitation of diminishing resources is the oil, gas and fission materials base of our energy dependent society. Data on known reserves vary greatly and estimates of the likely fruitfulness of new explorations are even more divergent. Judgments of the potentials for conservation, substitution, and technology development to protract the period before exhaustion also vary widely. Selecting and combining data with such substantial variation for purposes of projecting time intervals involved doesn't contribute to precision or credibility, nor does it basically alter the problem.

The combination of the most optimistic of estimates and judgments defines a highly critical problem. Whether the "present rate" projection calculates 25 years or 50 years before exhaustion is only a matter of degree in defining the absolute necessity of dealing with economic, social and political stresses of a major transition in energy usage patterns. Therefore, this report will not engage extensively in specific data selections, citations and interpretations related to energy sources or usage details. It will address the anticipated impacts of energy related problems on the agriculture and associated enterprises of the Great Plains.

The major adjustments in energy usage in the next 25 years will be added to a matrix of other major concerns including population growth, expectations of developing nations, international economics, increased food needs, environmental protection, and natural resource management. All of these are highly interrelated and they will all impact the Great Plains area. The economy and resources of the Great Plains...
Plains are such that the primary and more direct factors of the adjustment equation will be:

- World food production demands
- Environmental and resource concerns
- Energy conservation and conversion

Environmental and resource conservation concerns will be major factors, but to a large degree they are compatible with energy related concerns and adjustments. Food production capacity on the other hand would appear to be of counter interest to reduce energy usage based upon present production technologies and practices (Energy Related Impacts, 1976:1-2).

Energy usage in agriculture, agricultural production, food production, and the food system has been described by a variety of statistics. Most of the apparent variance is attributable to definition of the industry being described and the inconsistency of terminology related thereto. The following table presents a composite of inputs by several agencies and a breakdown of components which may more definitively describe the points of energy use (Energy Related Impacts, 1976:5).
### Food System Energy Consumption as Percents of Total U.S. Energy Input

<table>
<thead>
<tr>
<th>Component</th>
<th>Direct</th>
<th>Indirect</th>
<th>Capital</th>
<th>Transportation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>1.0</td>
<td>1.1</td>
<td>0.4</td>
<td>0.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1.8</td>
<td>2.5</td>
<td>0.1</td>
<td>0.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Distribution-Wholesale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Distribution-Retail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Consumption Preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Out-of-home</td>
<td>2.0</td>
<td>0.2</td>
<td></td>
<td>0.6</td>
<td>2.8</td>
</tr>
<tr>
<td>- In-home</td>
<td>3.3</td>
<td>0.3</td>
<td>0.7</td>
<td></td>
<td>4.3</td>
</tr>
<tr>
<td>Trucks</td>
<td></td>
<td></td>
<td>0.4</td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>Total (Food System)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.5</td>
</tr>
<tr>
<td>Estimated total, including fiber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.0</td>
</tr>
<tr>
<td>crops and forest products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This amount of energy use in the United States provides food and fiber for all of our people while at the same time, the bounty of our agricultural production has permitted the United States citizen to enjoy a high standard of living and at the same time has provided surplus to export agricultural products worth over $20 billion in 1975 and has contributed 80 percent of the food aid to needy nations. In recent years the products from nearly three in every 10 acres of United States agriculture have been exported. The nation's economy is increasingly dependent on maintaining and enhancing agricultural export levels to offset its purchases of non agricultural foreign products. This enviable position was achieved with fewer than three percent of our population directly engaged in agricultural production. But this efficiency has been achieved with ever increasing use of fossil fuel energy for power, fertilizers, pesticides, crop drying, and other production practices and operations (Energy Related Impacts, 1976:2).
In spite of this,

The food system should be considered in perspective (16.5 percent) of total energy usage and certainly food production operations (2.9 percent) should not be regarded as a primary point of energy usage relief. Indeed, it should be recognized as the energy synthesizer that it is (Energy Related Impacts, 1976:6).

In terms of architecture the use of energy seems to be much less efficient. According to Richard G. Stein, architects are responsible for an astronomical amount of the national energy use.

All told, with the 20 per cent in fossil fuel usage, the 6 per cent in industrial usage, the 12.5 per cent in source electric usage, and the 5 per cent of unnecessary transportation usage resulting from planning patterns, we are addressing 43.5 per cent of all energy used for all purposes when we examine the relationship between architecture and energy (Stein, 1978:14).

Some of the energy used in agriculture is even a result of architectural and planning decisions making agriculture an even more efficient sector of our economy. It seems that if the "God Architect" can ever become as intelligent as the "Dumb Farmer" we might survive in this world while allowing lifestyles to remain a matter of choice rather than being based upon energy-dependent decisions.

In respect to Hay Creek Farms, Inc., the use of energy to heat and light the buildings amounts to at least 1/6 of that used for the operation of the entire corporation. This then looks like one of the easiest places
for me to help save operating costs overall and is, therefore, a very important part of this project.

One other important factor to be studied is the possibility of energy production on the farm itself and possible methods of using such self-produced energy.
POSSIBLE ENERGY SYSTEMS

I. Methane. On Hay Creek Farms, Inc., with the total farm system envisioned, we would have a 300 head equivalent of cattle on feed for approximately 160 days each year. Of these, 225 would be cow herd and would be fed low concentrate and recycled manure rations; 75 would be bulls fed a high concentrate ration.

It would be possible to harvest the manure created and attempt to produce methane and protein supplement. The systems used to do this can be fairly elaborate or fairly simple but in order to reduce labor, a simple system would not be feasible nor is a system which only produces methane gas.

An early concept of the Cattle Waste Conversion System (CWCS) addressed itself to the disposal of the environmentally unacceptable accumulation of feedlot manure. However, it soon became evident that the fuel gas produced by fermentation did not provide economic viability by itself in most cases. Based upon testing and research, the sludge that remained from the fermentation process was found to be rich in crude protein, a basic element in cattle feed. The resulting concept then became one in which the feedlot wastes would be fermented to produce a methane fuel gas and a protein rich feed ingredient. Therefore, the feedlot, while being the raw material supplier, also became the end user of the recycled products (Neel, 1976:2).

Based upon research done by Hamilton Standard, the value of methane produced per animal per year at $1.50/m BTU, could approach $10.50. The value of protein feed supplement at $110.00 per ton would approach...
$46.00 per animal per year. This would result in a value per head per animal per year of $56.50. This would result in a total value recoverable of $3,715.00 per year for Hay Creek Farms, Inc., when the feeding requirements are inserted. When you consider the additional costs associated with this production; labor, methane converter, storage, sludge dryer, confinement facility, etc.; the maximum projected return seems very negative. For this reason, methane generation will not be tried. Instead we will try simple re-cycle procedures for the feedlot manure and attempt to obtain the feed value and fertilizer value at much less cost.

II. Alcohol. The use of alcohol as an alternate fuel has been and is presently being widely expounded. It is possible to produce alcohol with products raised on about any farm. To use this alcohol, mix it up to 20 percent with gas or up to 50 percent with diesel fuel; then use it as normal fuel. With changes in the vehicle's fuel system, 100 percent alcohol can be burned as fuel.

To produce this alcohol, grain or other residue high in sugar or starch is fermented and the alcohol is distilled. This process requires an external energy source for distillation and at present 130,000 BTU's of energy are required to produce 84,000 BTU's worth of ethenol alcohol according to Dr. James Kendrick, an agricultural economist from the University of Nebraska (Hill, March, 1980:32).
On a farm, of course, straw or hay or other things could be burned to supply that 130,000 BTU's necessary, but in almost every case it would require even more energy to collect and prepare it for combustion as well as vast amounts of time.

However, when alcohol fuel is produced on a larger scale, it can be energy efficient, even when using a nonrenewable fuel to supply heat to operate the alcohol-production plant. An example of this is a $400,000 steam-type still on the Gene Schroder farm in Campo, Colo. The still is owned and operated by the Schroder family, who farms 7000 acres.

The still produces 100 gallons of 200-proof ethanol an hour; currently it is being operated 12 hours a day. But soon Schroder plans to go to round-the-clock operation. The plant is fired by diesel fuel.

A study done by the Solar Energy Research Institute, a government agency in Golden, Colo., indicates that for each gallon of ethanol produced, 29,000 Btu of diesel fuel is used (this includes the heat used to cook the mash, as well as distillation). A gallon of 200-proof ethanol contains 84,400 Btu. When it becomes practical, Schroder plans to switch to a renewable fuel to fire the plant.

Milo, grown on the Schroder farm, is used as feedstock to make the alcohol. The ethanol is sold for two dollars a gallon.

There are several differences between the Schroder still and small stills you can buy or build. Some of the important ones are these:

- Cost: The Schroder family has spent two years and $400,000 perfecting its alcohol-production facility. Most individuals can't afford that kind of money and time.

- Efficiency: The plant makes extensive use of heat exchangers and heat recycling, something that small stills that are run only a few hours a week can't do very effectively.

A high-quality product—200-proof (anhydrous) ethanol—is the end result. With small, simple stills you are lucky to produce...
190-proof ethanol in any volume. A more likely figure is in the 160 to 180 range. And many simple pot stills may not be able to reach 160 with any consistency.

Once you get past 190 proof in the distillation process, you shortly run into something chemists call the azeotropic point. Past this point (which varies, but can be around 195 proof), you can distill all you want, but the ethanol doesn't get any purer. Special, expensive techniques must be employed to remove the remainder of the water. These techniques are not practical or economical on a small scale.

What does the future hold for individuals who want to make alcohol fuel? Professor E. Kendell Pye, a biochemist at the University of Pennsylvania and the director of its cellulosic conversion research program, says, "A farmer can't be expected to run his farm and a still, too. To produce any reasonable quantity of fuel, he would need to run the plant on a 24-hour-a-day basis--for a number of reasons.

"My feeling," he says, "is that the best way to go is for a group of farmers to get together, form a cooperative and run, say, a 10-million-gallon-a-year unit, and train and pay somebody who is technically competent to run the still--someone who doesn't have to go off and feed his chickens or plow the fields whenever the sun shines" (Hill, 1981:140).

This could be done by our neighbors and us if we could all agree to spend the money and work together. However, to do it by ourselves seems a little too much to expect.

Another problem for us is that we could use the grain as feed, straw and hay as feed or bedding, and the end result, manure, as feed and fertilizer. Further, these uses as feed and fertilizer build food for human consumption and improve the future productivity of the land rather than causing air pollution and reduced soil tilth. (Soil tilth is the ability of soil to hold and give up air...
and water which in turn allows plants to grow more easily as tilth increases. See page 65 in the Irrigation Section.)

III. Wind Generators. In looking at wind generators the Savonius (egg beater) is very efficient but is not self starting. This can cause problems in that you must have starter engines which can fail and then you collect no power. Regular 2, 3, and 4 bladed wing turbines are not as efficient as people believe they should be and NASA is even designing them with variable pitch ends on the props to allow for more efficiency. In my research I happened upon the Allison Wind Engine.
William Allison, an automotive engineer from Detroit, has developed a multiblade windmill that looks unlike any previously known windmill and, according to the designer, will outperform other wind machines (Wright & Stevens, 1980:64).

Dubbed "wind engine" by its creator, the windmill features four pairs of blades arranged in depth (shish-ke-bab style) along a horizontal axis at a measured distance and angle from each other. Though Allison has skewed as many as eight blade pairs and as few as a single pair, his tests show that four or more pairs have the highest efficiencies—extracting more than 56 percent of the energy in low velocity winds of eight to 12 mph. (Fifty-nine percent is the theoretical maximum that can be extracted by a wind turbine.) (Wright & Stevens, 1980:65).

In correspondence with Mr. Allison (dated May 13, 1980) about his wind engine, he states that with an average wind speed of 11 to 12 mph, his wind engine with a 40-foot diameter compound is expected to produce an annual average output
of approximately 15 KW per hour. Output in a 36 mph wind is projected at 75 KW/H.

The mean air speed at Williston, North Dakota weather station at 20 feet above the ground is 10.1 mph. By calculating the air speed at 100 feet above the ground from the formula height to the 1/7 power you get the average speed to be 12.584 mph which would give an average hourly output with the above mentioned wind engine of 17.75 KW. This would be 155,490 KWH annually.

This is, of course, an estimate and an onsite wind speed analysis should be made for at least a year before any actual money should be spent erecting a generator.

IV. Hydrogen.

You can't see the forest for the trees, goes an old saying. It translates to mean that the solution to a problem may be close, but is not readily apparent. Finding alternate fuels to replace our depleting petro supply is such a problem. According to the Billings Energy Corporation, the solution is literally right under our noses, but we don't see it yet.

Billings Energy Corporation, Provo, UT, has developed technology that converts most modern internal combustion engines to run on hydrogen. For the past ten years the company has been converting automobile, mobile home, garden tractor and even dwelling power sources to burn hydrogen, says Vaughn R. Anderson, director of hydrogen engine research for the firm.

"Our company was founded by Roger Billings, who had experimented with hydrogen even while in high school," Anderson explains. "Billings modified
a compact car to run on hydrogen when he was a college student. He entered it in a clean-air contest and won easily."

Billings won because all that comes out of a hydrogen car's tailpipe is water vapor. "A lot of times the air coming out is cleaner than the air going in," Anderson says.

Although hydrogen power is practical today, there remains the problem of supply, Anderson points out.

"To produce hydrogen economically, you have to use it on a large scale," the research director says. Right now it is still expensive to separate hydrogen from oxygen, if it is done on a small scale. The Billings Corporation has the hydrogen engine technology close to practical application, Anderson says, now they are working on the hydrogen supply.

"We have to work from both ends. The engine is not practical without a large supply of hydrogen, and we will not have a large hydrogen supply until there is a high demand."

The most economical source of hydrogen currently available is from coal gasification, Anderson says. Combusting coal dust with steam produces carbon, oxygen and hydrogen. The carbon bonds with the oxygen to form CO leaving the hydrogen in a recoverable form. By further reacting the CO with water (H2O), the CO will grab another O leaving H2 or twice as much hydrogen.

Anderson explains that it makes more sense to use the hydrogen from this process than to continue the reactions to further gasify the coal.

"Before, all the hydrogen produced in coal gasification was simply considered a by-product. But by using the hydrogen as the primary fuel, even greater savings in net energy are realized than by the complete gasification of the coal. And with all the coal we have in this country, it makes sense to convert it to hydrogen. We would have a virtually inexhaustible supply of energy," Anderson explains.

Anderson says hydrogen would also be compatible with the natural gas pipeline distribution system already established.

The consumer would purchase pure hydrogen at the gas pumps (literally gas pumps for hydrogen).
Anderson explains. Currently hydrogen costs approximately $.40 per gallon for the energy equivalent of gasoline. However, as some people can still remember, hydrogen was the fuel used by the Hindenburg zeppelin that exploded in a flash fire in 1937.

"We have a developed fuel system that makes hydrogen virtually safer than gasoline," Anderson answers. "By combining hydrogen with certain metals (forming hydrides) it becomes very stable. When a smaller amount of pure hydrogen is introduced to a tank containing these hydrides, the hydrogen reacts with the hydrides and heat is produced. But as long as the hydrogen is in the hydrides, it is very stable."

In a recent experiment to prove the safety of hydrogen, Billings Energy Corporation engineers shot a tracer bullet into a hydride tank, like one used in a hydrogen powered car. Nothing occurred in contrast to the explosion that occurred when another tracer was fired into a conventional gasoline tank.

To convert a vehicle to hydrogen is relatively easy, Anderson says, although such a vehicle is more expensive currently than a similar gas model.

"The hydride tanks are very expensive at the present time, and they take up a lot of room," Anderson says. "Our next goal is to find lighter and more economical hydrides to use in the tanks.

A hydrogen-powered vehicle runs quieter and somewhat smoother than a gasoline powered model because hydrogen produces equal power with less fuel combustion. Flame speed of hydrogen is ten times faster than gasoline, Anderson explains, therefore it ignites faster and the engine runs smoother.

In addition to the hydride tanks, the only other modifications needed to convert a gasoline engine to hydrogen is a special carburetor and the necessary plumbing. Engines would even be simpler in most cases because emission equipment would not be needed. Fuel efficiency would be increased by about 30%, Anderson says, but current hydrogen costs equally offset that savings.

When will we be using hydrogen cars and can the fuel be used in farm tractors and trucks? Anderson explains that for the most part, we could have hydrogen cars today, if we had an abundant
supply of hydrogen. Until then, his firm is manufacturing a hydrogen producing electrolysis system that can fit into most garages. Most of our experimental vehicles use this unit to produce hydrogen for their cars, but it is still pretty expensive, Anderson says.

The U.S. Postal Service is currently testing a delivery Jeep outfitted with hydrogen power and Riverside, CA has several buses running on hydrogen.

"Here in Utah we have built an entire home that is powered by hydrogen, right down to the stove," Anderson says. "It is the first of 36 homes that are being built in our 'Hydrogen Homestead' plan to totally heat, cool and power an entire development with hydrogen."

Conversion is also underway of a diesel bus, Anderson outlines. Diesel engines are easy to convert, however the ignition system must be altered to either a sparkplug type of system or diesel fuel must be used to begin the ignition process. That sounds complicated, but most of our test vehicles are dual-powered setups now, he says.

Other immediate applications of hydrogen power are being used in the mining, mass transportation and warehouse industries where exhaust emissions are critical factors.

The closest vehicle we have to a farm tractor is the Jacobsen lawn tractor we converted to hydrogen power, Anderson says. It is used at the Homestead for all lawn and grounds chores. The 20 hp tractor uses a converted Kohler engine, he explains.

However, because of the higher efficiency, longer life and reliability of the hydrogen engine, Anderson sees farm tractors as very practical applications within the next few years.

"We want to perfect the system before we begin pushing it commercially," Anderson says. "The electric cars are a good example of what can happen when you enter the market too soon. They had too many flaws and many of the early users were disappointed in their performance. Today they are working great, but they have a bad reputation to overcome. We don't want that to happen with hydrogen."

Refinement and proving reliability are the immediate goals in Billings Energy Corporation's hydrogen research efforts, as well as developing cheaper sources of hydrogen from refined
gasification technology. Hydrogen is not here yet, but it is one alternative fuel solution that will stay "right under our noses," until the technology is complete (Henry, 1979:11).

Since that article was written I have visited at Forest City, Iowa which is now planning a coal gasification plant to produce hydrogen. I have seen one of the hydrogen powered cars and Billings Energy Corporation has moved to Independence, Missouri, where I visited, and looked at a large hydride tank and a hydrogen powered bus and discussed the use of wind power to generate electricity with which to produce hydrogen through electrolysis.

Since that time, new developments in the production of hydrogen through direct solar technology have been reported.

Prof. Harry Gray, chairman of Caltech's Division of Chemistry and Chemical Engineering, and his colleagues, had designed a remarkable new chemical compound, with two rhodium atoms at the hub of a windmill-like structure composed of carbon, hydrogen, and nitrogen atoms. When the compound in water solution was exposed to sunlight, it transformed solar energy into chemical energy that split water molecules and released hydrogen gas--one of the most desirable of all fuels. One of the handicaps of the process, however, was its very low efficiency--about four percent. Recently, Dr. Gray announced at a meeting of the American Assn. for the Advancement of Science that further experiments show the possibility of using the "solar catalyst" to yield hydrogen with an efficiency of 90 percent (Fisher, 1980:61).

There have also been further advances in storage.

Researchers from International Nickel's Research and Development Center have recently released experimental data from tests on a hydride which displayed resistance to poisoning.
"We found," said G. D. Sandrock, co-researcher for Inco, "when we compared 'lanthanum nickel five' with two other commonly used hydrides, LaNi5 was particularly resistant to poisoning by oxygen and water vapor."

Hydride poisoning has been a problem with the various iron-titanium alloys when exposed to impure hydrogen. The result is deactivation of the exposed surfaces.

"Generally," continued Mr. Sandrock, "we found that all three hydride compounds tested could be reactivated relatively easily, but the reactivating process would be unnecessary when we can build poisoning resistance into alloys" (Poisoning Resistant Hydride Developed, 1979-80:5).

Along with that, they are developing new ways of storing hydrogen safely besides hydrides.

Robert J. Teitel Associates of San Diego, California, in a program sponsored by the U.S. Department of Energy, is developing an exciting new method of storing hydrogen using microspheres.

"Microcavity technology," explained Mr. Teitel, founder of the San Diego based firm, "was originally developed almost eight years ago. As I worked with microsphere technology, I discovered that it could be a means of storing large quantities of hydrogen under high pressures."

According to Mr. Teitel, when the tiny powdered sugar-like microspheres are heated to 350 degrees Centigrade, pressurized hydrogen molecules pass through the glass walls into the hollow center of the spheres. When the spheres cool, the hydrogen is trapped inside.

The hydrogen is retrieved from the spheres by reapplying heat in a similar fashion to its hydride counterpart.

Thus, if microcavity storage proves technically viable, the microsphere vessel could replace the heavier hydride tank in current hydrogen-powered vehicles (Microsphere Storage Investigated, 1979-80:6).

Washington, D.C. researchers from the Carnegie Institute's Geophysical Laboratory have created for the first time solid hydrogen at room temperature.

According to a SCIENCE NEWS article, Ho Kwang Mao and Peter M. Bell applied 7.4
million pounds per square inch pressure (57 Kilobars) to a hydrogen-filled chamber. The resulting liquid hydrogen produced by the high pressure popped instantly into clear granular solids resembling sugar or salt.

Though the hydrogen existed as a solid only briefly, it was the first step in producing a room temperature hydrogen solid which would provide a super conductor of electricity and could be used in energy production. It is believed that with one megebar of pressure, the hydrogen molecule would break up into individual atoms causing a permanent hydrogen solid (Hydrogen Solid Formed at Room Temperature, 1979-80:7).

It is my belief that with electricity generated by wind generators in off-use times, hydrogen could be produced through electrolysis, stored, and used later. This hydrogen could be used for about anything requiring energy on the farm. By using a hydrogen powered generator or fuel cell, electricity could be produced when the wind generator was out of wind and all other machinery and furnaces or dryers could be converted to hydrogen. The problem from this point is to determine the amount of energy needed by the farm for all uses, calculate the inefficiencies of the conversion processes and then with known average wind conditions determine the size of wind generator and storage vessels required. Again the house could take quite a lot of energy and must be figured into this.

This energy produced in this manner would not be as cheap as conventional energy is at this time but the difference in costs will lessen as time goes on. This is also a totally non-polluting, renewable and
additive energy source versus the other pollution causing energy sources we have studied.

DESIGN CONSIDERATIONS

I. Functionality. When designing a building, master plan, energy system, or any object intended for actual use, its ability to function as required is the prime consideration.

If in the design of the energy system, irrigation system, and farmstead for Hay Creek Farms, Inc., the ability of any part of it to function properly and efficiently were overlooked, it could result in bankruptcy, destruction of the soil, excess energy use, and time loss in respect to labor. No matter how the project looked, it would be a failure if it did not function. I toured a farmstead in Nebraska last summer which was overbuilt and it excited everyone on the tour visually; yet, no one wanted the place. If there were not people like Dr. Arrmand Hammer (who owns Occidental Petroleum and other companies and has the farm for a tax break), the place would most likely be sitting vacant and probably would be vandalized besides. This place has, in fact, caused Bill Smith with Shalco Cattle Company, Dave Canning with Colossal Cattle Company, Preimer Angus, and one or two other firms, severe financial distress in the past ten years.
Shelter--one part of the functionality of a place is the shelter it is expected to provide. In this case there must be partial shelter provided for the cattle to protect them from wind, rain, and snow, and total shelter for the people for work, play, and comfortable living.

II. Environmental respect. The whole project must have respect for the environment in which it is located. If such a project were not approached in a respectful manner, you could have an environmental disaster. Going back to the Nebraska farm, one of their projects was to level a large piece of land for irrigation. They did not respect the fact that the soil type was wrong and the fact that the water table was close to the surface. All they got for their work and money was a man-made slew which would only grow fireweed and ragweed. In this project I want to remember not to destroy the value of the farm by ignoring the environment.

III. Human psychological needs. Projects are all looked upon by people and owned by people. Because of this, there are values which cannot be measured by dollars or other measuring devices. Due to this, projects must through their design, construction, and use, create an atmosphere which gives rise to pride, satisfaction, and even awe. To think or believe that the project you own, worked on,
designed, or just love to drive by, is better than any other, or that it is the first of its kind, or some such fanciful thought or fantasy, creates feelings toward it similar to those you feel when falling in love with the world's most beautiful eligible person.

When actually using a project, particularly a building, light and air, feelings of freedom, feeling sheltered and safe, are all needs which must be satisfied by it. Think of living in a little round culvert in which you could not even stand or in a glass box in the center of the Houston Astrodome. Neither would be comfortable even though you would be sheltered and would have your own space. In order to provide those people who will use your project the feelings of satisfaction and awe you might wish, it is necessary to have empathy with them. This ability to empathize with others may be that which makes a designer good while a lack of empathy could destroy a designer no matter his ability to create spaces, decoration, proper and exciting color coordination, or other design features. It may even be this ability to empathize that makes such people as Goff, Sullivan, Wright, and Aalto so well thought of and admired while other people who may be equally creative are not even remembered. Each pencil stroke on a drawing has the potential to affect someone emotionally. Hopefully those emotions will be happy rather than sad.
IV. Design decisions in relation to energy. In designing a project it is necessary to think of the use it will make of energy both human and natural. The materials used both use and conserve energy in varying amounts. It requires human energy to maintain a project as well as to provide for the maintenance of the project.

Materials, the design in relation to natural energy conservation, the maintenance of the project, and all other energy uses must be weighed in relation to the future costs as well as the present costs. I feel cost analyses should be made for as many decisions as possible, especially energy, in the same manner any good business decision is made--without emotionalism and using as much valid information as possible.

In the planning for construction of the buildings for the new farmstead, it was found that:

More energy is consumed in the construction of a building than will be used in many years of operation. Building materials and equipment require considerable quantities of energy during their manufacture, transportation to the construction site and assembly. Robert A. Kegel, in an article concerning energy and building materials ("The Energy Intensity of Building Materials," Heating/Piping/Air Conditioning, June 1975, pp. 37-41), analyzed the energy consumption of a conventional educational facility (432,000 sq ft) in Chicago. He looked at the building from the standpoint of building construction, materials, equipment and operation. His results indicated that
the building could operate for over 6 years before exceeding the energy it took to construct it. These results did not include the energy expended in mining and transporting materials to the mill or factory. Conventional housing reflects similar patterns of energy use (Mazria, 1979:115).

There are two available methods for reducing the energy that goes into the making of buildings: first, in the reduction in the amount of material, and second, in the selection of the material requiring least energy to perform a certain function. For proper decisions, a detailed framework of all the energy uses in materials, products, and complete assemblies is required.

Considering the importance of these decisions from a national point of view, it is astonishing that such basic data are unavailable. Moreover, the categories for reporting are in many instances not identical (Stein, 1978:92).

Mazria believes you should follow these recommendations (they are his).

In building construction, use mostly biodegradable and low energy-consuming materials which are locally produced. For thermal mass and bulk materials use adobe, soil-cement, brick, stone, concrete, and water in containers; for finish materials use wood, plywood, particle board and gypsum board. Use the following materials only in small quantities or when they have been recycled: steel panels and containers, rolled steel sections, aluminum and plastics (Mazria, 1979:115).
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<td>10% soil-cement block</td>
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Sources:  
For this project a three bedroom home with a two car garage, kitchen, dining, living, family, utility, office, two entries, three baths, a mechanical room, a hydrogen room, and root cellar will be designed and studied. In fact, two such houses will be designed and studied. The houses will be super insulated, above ground, and one will have an attached greenhouse. In each case the materials used will be calculated for energy use, fabrication, and construction, as well as maintenance, heating, and cooling. Hopefully a house design can be achieved in which the energy savings will more than pay for the costs of construction required to save the energy based on an amortization rate comparable with the current market and projected energy costs.

This house must also satisfy the emotional needs of people such that the feelings of awe, satisfaction, or pride will be evoked. I also want it to evoke the feeling of living well in its environment.

Use requirements of house spaces:

Front Entry:

- Closet space for coats and boots
- Area for a small seat
- Double door air lock system
Rear Entry:
- Closet space for work clothes and boots
- Clean-up area (sink and floor drain)
- Double door air lock system

Office:
- Computer area
- Drafting area
- Records area
- Work area (desks)
- Business conference area

Kitchen:
- Mixing area (snack bar combination)
- Range with standard oven and micro wave oven
- Double wide refrigerator with ice maker
- Pantry area
- Double sink
- Telephone and home center

Dining:
- Area for table with 12 chairs
- Area for hutch

Living:
- Area for baby grand piano or organ
- Sofas and chairs for 10
Family:
Sofas and chairs for 12
Shelf area for books, stereo, and television
Fireplace and barbeque (outdoor ducting for combustion air)

Utility:
Washer and dryer with laundry sink
Ironing board
Closet
Sewing area (may have to use snack bar in kitchen)
Linen closet

Bedrooms:
Master bedroom with walk-in closet and bath:
  Area for king size bed
  Sitting area
Standard bedrooms
  Standard closets
  Area for single twin size bed
  Area for dressers
Baths:
  Public area bath:
    Shower
    Water closet
    Sink
    Towel cabinet
  Master bedroom bath:
    Shower and tub with whirlpool
    Double sink
    Water closet
    Towel cabinet

Root cellar:
  Freezer
  Bins for vegetables
  Shelves for canned foods

Garage:
  Two car spaces
Hydrogen room:
- Hydride or microsphere storage area
- Hot water tank
- Electrolysis machine
- Furnace
- Access to outdoors for fueling cars and machinery
- Area for hydrogen-powered electric generator or fuel cell

Orientation:
- Greenhouse must face within 20° of south
- Garage and hydrogen room must shelter north side of house. Winter winds are usually from the north.
- For summer ventilation there should be a cross ventilation from ESE to WNW. Summer winds blow mostly from the southeast.

Organizational Relationships:
- In a farmhouse the kitchen area is the center of activity and actually becomes in many cases the center of all the farm. For this reason a kitchen must have a view of the farm yard and driveway which allows those people in it continual visual contact with farm activities.
- The kitchen must be close to the dining room and should be close to the garage, both entries, an alternate way
the root cellar, the utility room, and the family room. This really means that the kitchen is the center around which one must plan everything else.

The dining room, of course, needs to be adjacent to the kitchen and should be close to the living room. In this house the dining area is expected to be expandable into the living room.

The living room in this instance is the formal room of the house, that room which in times past was called the parlor. This room should be near the front entry and, of course, for this house the dining room.

The family area or non-formal area is the bedrooms, utility room, baths, kitchen, family room, and to an extent the dining room.

The most private areas in the house are, of course, the bedrooms. These need to be close to the baths and for ease of maintenance the utility room.

The family room should be near the kitchen and entries and can be located such that it is a separation area for the public living and private bedrooms.

The baths' main use comes from the bedrooms and should be close to that area. Also due to our societal mores they should be screened from public areas.

The garage must be adjacent to an entry and near the kitchen.
The root cellar also must be adjacent to an entry and near the kitchen.

The office being a public and private space needs to be near an entry, yet separate from the family space. Due to the fact it holds the computer and controls for the hydrogen room, proximity to that room is dictated. Also, since it is a public office it needs a bath. The drafting area should be separated from the entry for work efficiency and the business conference area needs privacy control.

The mechanical area should be located such that it functions easily with the rest of the house.

The greenhouse must be near any entry and have a southern exposure. In order to function such that the house can work as a passive solar collector, the rooms which must have windows must face south. That means that the living room, family room, and bedrooms must have a southern exposure. In this house, due to its siting, the kitchen must have a north window and the dining room an east in order to allow adequate visual connection between the outdoor activity and the people in the building.

Other rooms which can survive with mechanical lighting and ventilation can be located on the north side or west end of the house.
Cattle sheds:

Enough length to shelter all calves while they eat at fenceline feed bunk under roof

Provide wind protection during storms

Orientation:

Open face to south or southeast
Long axis east-west
Roof slope to north or northwest

Barn: Sale--Show--Calving
Sale ring for five 800# animals
Seating for 200 people (removable)
Pens for calving. Removable for sales if necessary
Pens for show cattle

Graneries: Exist

Machine Shop: Exists
Machine Shed: Add to Machine Shop

Must be deep enough for a truck with a 20 foot box

Must hold approximately:

3 tractors
1 field chopper
1 swather
1 truck
2 pick-ups
The building site is located on the west side of a normally dry creek bed and below the rim of a hill to the west and north. The site slopes generally to the southeast, which is the best situation for a modified micro-climate in the northern latitudes of the northern hemisphere. There are no natural trees on the site but the existing shelter belt has about twelve years of growth which makes it quite effective. Note that both the sedentary and nomadic Indians picked similar sites with natural timber for their winter homes.

The trees not in the windbreak are to be planted for two purposes. One is the visual effect and the drama they create by rhythm and direction. The other is the fact that they also act as climate modifiers. In fact recent studies show that spaced trees such as these are have a greater ability to modify wind speed than continuous rows do.

Combining the windbreak with the spaced trees, therefore, creates a much larger area of modified climate.

In the winter when most wind comes from the north and west, the ridge of hills with the shelter belt slows the wind and protects the buildings. The house is, in fact, close enough to the windbreak to be within the saltation area it creates during a snow storm and will,
therefore, get snow buildup on its roof greater than the normal snow depth. This will help insulate the house as the snow acts as a natural blanket.

In summer the rows of trees combined with the windbreak act as a natural funnel for the normal south to southeast breezes. This will cause their speed to increase and they will, therefore, cool the house more effectively. Note that the Indians knew enough to put their villages on hills and plains in summer where the cooling breezes were best. (We have to create such situations as we seem to think one building and site has to do all things.)

The feedlots and sheds all have slatted windbreaks or other protection to further reduce winter winds yet have south fences which allow summer breezes through.

Further modification of the natural weather is produced by the rows of hay and straw stacks, the location of which is also central to the feeding area as are the silage pit and granaries.
EAST ELEVATION

SCALE 1/16" = 1' 0"

FARM HOUSE
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*Earth Sheltered Housing, 1979:69

**Heating and Cooling Calculations**

House Volume 28,740 cu. ft. Holds 517.32 Btu's/°F/°H
Heat Loss Per Degree F. Infiltration with air to air heat exchanger running
0.50 C.F.M. and 99 percent eff.
with shutters open 38.91 Btu's/F°/H.
with shutters closed 18.22 Btu's/F°/H.
Building Above Grade
with shutters open 152.487 Btu's/F°/H.
with shutters closed 96.048 Btu's/F°/H.

**Building Below Grade**
19.285 Btu's/F°/H.

**Fixed Heat Loss**
5130 Btu's/Hr.

**Maximum Heat Loss**
0 - 35°F., with shutters open 21,465.99 Btu's/Hr.

**Heat Storage**
12,410.908 Btu's = 3636 Kilograms of Sodium Sulfite

Provide all heat required above solar gain from November to April 40 percent safety factor.

---

**House Without Greenhouse**

**Heat Gain and Loss Calculations**
## HOUSE WITH GREENHOUSE

**HEAT GAIN AND LOSS CALCULATIONS**

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<td>87,651</td>
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*Earth Sheltered Housing, 1979:69

**Building Below Grade**
19.285 Btu's/Ft²/Hr

- Fixed Heat Loss 5710.65 Btu's/Hr.
- Maximum Heat Loss 0 - 35°F. with shutters open 38.129.15 Btu's/Hr.
- Heat Storage 4,500,000 Btu's = 1356 Kilograms of Sodium Sulfite
- Provide total heat needs in January for 12 sunless days.
THE CONSTRUCTION TYPE

This house is an above ground, super-insulated structure (using R 40 walls, R 60 ceilings, R 30 floors, controlled infiltration with an air to air heat exchanger and airtight vapor barrier, insulating shutters on all windows, and air lock entrances), a construction type which was developed in Canada. While doing this project I visited a house of this type in Regina, Saskatchewan, Canada which was built by the Department of Mineral Resources of the Saskatchewan government.

That particular house took one-tenth of the energy for space heating that a typically constructed modern house of the same size takes in Regina. They used active solar collectors but due to their improper location for snow blanketing and the limited amount of heat storage they did not work.

I was originally going to design an earth sheltered house (the only indigenous architectural type to the Great Plains; see Mandans) as well as an above grade house, and study their energy use from initial construction to the end of a five-year period. But while studying the different construction types, standard construction and earth-sheltered, I also found that the super insulated house in Canada was working out very well. This led to a comparison of all three types and I soon found that the super
insulated house should take the least energy of all three over a period of years.

After looking at these results (I will admit that my energy use data is limited but should be fairly close) I abandoned the idea of an earth sheltered structure and a standard construction type as it appears neither type would be able to save more energy through their life cycle than a super insulated structure.

To further reduce the energy used by this house I have incorporated some recent technological developments. One is a window system called Heat-Mirror.

Briefly, Heat-Mirror in its most efficient form is a double-glazed window with a thin Mylar film between, but not in contact with, two panes of glass. The film is treated with several invisible layers of metal to form a surface that will reflect thermal radiation, thereby trapping heat within a building more effectively than ordinary glass. The U-value of this product is about 0.2 compared to 0.55 to 0.60 for double glazing; therefore, heat losses are reduced by a factor of approximately three. The Heat-Mirror is completely invisible and permits solar heat to enter a window almost as effectively as if it were not present (Kreider, 1981:14).

This gives the glazed areas of my house an R 5 value which is very good for glass.

The Plains Indians (sedentary and nomadic) realized that an environmental modification solution for one condition did not necessarily work for another condition. Due to this their shelters were made for adaptation
to changes in weather. Examples of this are the smoke flaps which closed for rain on the tipis and the movement from summer lodges to winter lodges by the sedentary tribes.

With modern technology, this house has features which help it to adapt to climatic and weather changes also. It does not up and move or turn to the wind as tipis could but the site is chosen and the trees planted to help modify the changes in weather (see site plan analysis). Also, there are operable shutters, with an R 20 insulating value and air seals on all windows and over the greenhouse and office area. These shutters can be used for sun control, air leakage control, temperature control, and still allow people the emotional release provided by the ability to have an outdoor view. The office area also has controlable vertical ventilation which allows for use of natural physical laws to control the interior environment.

Further, this house uses some of the extremes in heat to help to modify the extremes in cold by a new method of heat storage, this being an advanced heat storage and heat pump system developed in Sweden called Tepidus.

If you could store summer's abundant solar energy for winter use, rooftop collectors could supply a family's year-round heating needs.

That dream of free energy was the starting point for Professor Ernst-Ake Brunberg, a physicist at Sweden's Royal Institute of Technology in Stockholm. Though practical long-term energy storage has stumped scientists for years, Brunberg thinks he has the answer: a chemical heat pump.
Like a heat pump, Brunberg's Tepidus system transfers heat (against the laws of thermodynamics) "uphill" from a cool place to a warm one. Unlike a heat pump, Tepidus doubles the energy extracted from the cool place, augmenting it with a chemical reaction that generates its own heat. And, unlike other types of chemical heat pumps [PS, Oct. '78], Tepidus can store energy indefinitely.

Since last November, the Tepidus system has been on trial in a five-room house near Stockholm with 100 square meters of floor space. Eight giant salt tanks, called accumulators, are crammed into one end of the basement. They're fed from 40 square meters of solar collector panels, which should provide for a whole year's heating needs. There is no other energy source, so no fuel bills.

A real breakthrough? Brunberg claims a good deal for the system. It has a remarkable energy-conversion efficiency of 95 percent, he says, and very high energy density compared to other storage media such as water, rocks, or phase-change salts. Brunberg also claims low losses for the system, which has few critical moving parts. And sodium sulfide (NaS₂), the chemical used, is cheap and needs neither replacement nor attention once installed.

This simple salt is key to the system's energy-storage cycle. Sodium sulfide is a hygroscopic salt--when it absorbs moisture, it heats up. That's what happens when you mix caustic soda with water to clean a clogged drain--the water molecules chemically combine with the salt, forming a hydride and releasing heat. Sodium sulfide has an added advantage--it won't dissolve if it's just dampened with water vapor. So a tank of damp salt can provide a bank of stored heat for warming a house and heating water.

Once the salt cools, it can be "recharged" by solar energy or waste industrial heat. Heat dries the salt, giving it the potential to reabsorb moisture and regenerate chemical heat. The vapor driven off flows to a second container, where it condenses and is held ready to wet the salt again when direct solar energy falters. This reversible cycle can be repeated indefinitely.

But Tepidus is more than an energy-storage system--thanks to the crafty method Brunberg devised to provide the water essential to the process.
The salt tank is connected to the water tank via a single pipe. The system is sealed, and the air pumped out. At this ultralow surface pressure, water vaporizes at 10 deg. C (50 deg. F)—the temperature underground. So the water tank is plugged into the ground via a heat-exchanger coil.

"Upgrading of cold energy from the ground is the heat-pump action," says Kjell Bakken, managing director of the Tepidus company.

Because of the low pressure, there is already some water vapor present in the system. "By the nature of the salt used," adds Bakken, "if both tanks are at the same temperature, the vapor pressure on the salt is lower than the vapor pressure on the water.

"So two things happen. Because of the pressure differences, the salt wants to draw water vapor out of the water tank. That means the water needs to be evaporated. And to be evaporated it needs energy. That energy is taken from the outside—from the ground coil.

"When the vapor reaches the salt tank, it condenses. So you get back the heat taken from the ground at the same time as chemical energy is released in the hydration reaction."

The system reaches equilibrium when the temperature in the salt tank is 55 deg. C (131 deg. F) hotter than the water tank. Then the pressure in the two tanks is equal, and the chemical sponge no longer absorbs vapor. Disturb this balance, and vapor is released from one tank and flows to the other. The direction of flow depends on which way the temperature swings.

Because the system is so sensitive to minute pressure changes, the working temperature of the salt tank remains constant at about 65 degrees C. That's enough for radiators and tap water.

But what about long-term energy storage? Tepidus has an enormous capacity. One kilogram of sodium sulfide can store and give back one kilowatt-hour (3413 Btu) of heat. In practical terms, that means that eight tons of the dry material can store and deliver 8000 kWh (27,304,000 Btu). That's
enough to meet the space- and water-heating needs of a small, well insulated house. The energy input can come from solar power alone—even assuming half the year's energy collection has to be stored for winter.

Eight one-ton salt containers, each one meter square and 1.75 meters high, make a pretty massive bulk to fit in a basement. Their volume is around eight times that of an oil tank with the equivalent thermal content. But one load of salt lasts a lifetime and soon offsets the penalty of dead space.

And Tepidus is far ahead of other forms of heat storage, according to Bakken. One main rival is eutectic salts that rely on the heat released during phase-change [PS, Oct. '78]. "These have a capacity of about 100 watt-hours (341 Btu) per kilogram, one-tenth of our energy density," says Bakken. "And the stored energy doesn't last long because it's 'sensible' heat—perceptible to the touch—and is gradually lost to the environment.

"By contrast, ours is a low-temperature and long-term system. It can be switched off for an indefinite period and allowed to cool to room temperature. When it's started up again, only four or five percent of the total energy is used for reheating it."

And, in many installations, the storage tanks need not be so massive. The present system's capacity to store a full 50 percent of annual heating needs is calculated for Stockholm's latitude. At lower latitudes, solar input is more evenly spread around the seasons, so the solar collectors could take more of the direct heating load.

The system opens up exciting possibilities. Energy input could come from waste heat produced in factories, such as paper mills and steel plants, as well as from sunshine.

Portable heat is a further possibility. Since the energy potential is trapped in the dry salt when it is fully charged, the sealed tanks can be disconnected and moved for hookup to a distant system as an instant heat source. Brunberg's company is designing salt-tank cargo containers for standard flatbed trucks. Surplus heat from nuclear generating stations and other plants could be delivered to remote areas in this way. Travel would be completely safe, since the
tanks contain nothing explosive, and the dry salt has neither high temperature nor high pressure. And since salt-tank modules can be any size, they could be scaled down for campers or pleasure boats. The salt could be charged by waste heat from the engine or at a special heat-input stations at camp sites or marinas.

Finally, the system could also be used for air conditioning. Since the 55-deg.-C differential can be locked almost anywhere on the temperature scale, the heat exchanger for the water tank could be placed in the room to be cooled or in a cold box. Air in the cold box would hover near the freezing point as heat was extracted by evaporation inside the tank.

What are the snags? "We've fully proved the principle in our pilot plants," Bakken says. "Due to the late installation, long after the sun had left Scandinavia, we had to charge the system with resistance heating," he adds. "But it was fully loaded in February, and we heated the house from then on. Now we're charging the tanks again for winter."

Bakken also reports that another pilot system, with a storage capacity of about 30,000 kWh (102,390,000 Btu) has recently begun operating.

"The critical salt material has given no trouble," he says. "We've run 150 charge-discharge cycles already—which could equal 150 years' normal operation—and the salt has not deteriorated. But accelerated cycling isn't good enough, as it may give spurious results. Only when we are able to test complete systems for 30 years can be say there are no problems.

"Our goal now is to improve component design to cut production costs. There are no dark areas, only problems of technical detail. Heat exchangers, for example, become very expensive when you're handling lots of power.

Initial cost could be a problem. Bakken figures a complete Tepidus installation for an average family house would cost four or five times as much as an oil burner. But he notes that the solar collectors would be a major item. "And remember we're talking about a one-time investment that you have to balance against future bills." That balance could favor Tepidus as fossil fuels become costlier (Scott, 1980:52).
FINAL ENERGY REQUIREMENTS

The charts on the following page show energy use, energy production potential for two wind generator sizes if they are 100 feet above grade and the percentage losses you must expect if changing energy forms.

From these charts I have calculated a total energy need of 1,038.95 million Btu's per year, which requires four 45 foot diameter wind generators. These four generators should provide 1,139.96 million Btu's per year which is about 10 percent above the farm's needs.

There is also a need for a 55 kW capacity fuel cell and storage capacity for 130 million Btu's of hydrogen, or about 1600 pounds.

Hydrogen storage through hydrides is so expensive at this time that I have decided to build underground pressure vessels to hold the hydrogen in a gas form at about 500 pounds to 600 pounds per square inch. This would require about 8,000 cubic feet of space and needs to be located such that an explosion would not damage the rest of the farm. Pipelines can then supply hydrogen to the places needed while keeping the amount present small enough to be relatively safe. The hydrogen room as provided would still be in use as it would be used to hold hydride tanks for recharging and the electrolysis machine for producing the hydrogen and oxygen.
## energy used by the farm

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## inefficiencies of change

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<td>FUEL CELL - HYDROGEN TO ELECTRICITY</td>
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SHELTERING FROM THE WIND

Besides trees and hills for shelter from the wind, we also use fences and sheds as windbreaks. There are always problems to overcome and one of these is caused by land blown snow around these windbreaks.

As this project is supposed to solve problems, I made an attempt at finding a way or ways to solve this snow drifting in our feedlots and around the sheds through computer simulation.

On the following page are the results of those simulated wind conditions.

The wind speed used was 35 m.p.h. and for each situation the program was run long enough for equilibrium to be reached. (The program used was also used to study avalanche prevention on Bridger Mountain, and by starting with their final results we eliminated a lot of trial and error.) When equilibrium was reached, visual appraisal of the results allowed determination of the drifts to expect. It was my goal to reduce drifting to the smallest amount.

I believe I managed to achieve some improvement in the performance of the windbreaks and have incorporated the results in the design of the cattle sheds.
these top three studies show expected snow drift patterns (fully drifted) using a coarse computer grid. 1.5 m high x 2.0 m wide. the bottom six use a finer grid, 0.5 x 0.5 m allowing for more accurate results. the wind is from left to right at about 35 mph.

SNOWDRIFT FORMATION STUDY
LITERATURE CONSULTED


Successful Farming (April, 1980), B2-B4.


PLATE SOURCES

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Plate 12  Plate 15
Plate 13

Plate 2
Plate 6
Plate 7

Plate 3  Plate 9
Plate 4  Plate 10
Plate 5