

Know how to do

Wood kiln drying

A Field guide



UNIDO Technical Assistance Program
Strengthening Forestry Training Centres and Wood Industries for Green Employment in the SADC Region



AIKAGROUP

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Words of appreciation

This publication mainly addresses the actors in the field. It has been designed as a tool to shape and prepare sustainable wood drying operations with limited resources and close to raw material sources.

We trust that this manual will provide you with a practical tool to develop the lumber drying opportunities in your country. Furthermore, it should be a thematic introduction not only for all who are involved in the process of forest products development, but also for those which do not dispose of full background knowledge in this specific field.

Special gratitude has to be given to Mr. Sean Paterson, UN Unido, who made his experiences and advice available for this field guide.

Foreword

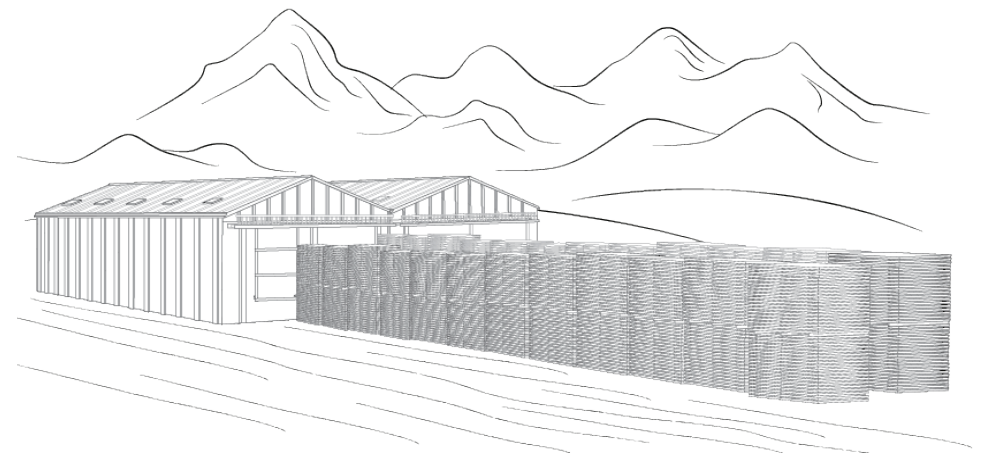
Wood drying is a fundamental and necessary element to utilise the biological resources in a sustainable way.

Communities can enhance their living conditions by taking part in wood drying operations. It creates job opportunities, trade, income, skills and is relatively simple to start with. If the demand increases, there are various possibilities to make the wood drying activities more efficient by means of gradual investments.

This field guide addresses a specific target group of players in the field - those people who initiate the project and bring the ideas to the communities

and project owners. They define the project and are responsible for its initial implementation. The field guide should be used as a tool to shape the project in a professional manner so that it can be used as a base for the execution of the project.

Simultaneously, this field guide can be effective as an introduction tool to those individuals who deal in the processing of timber, wood cuttings and the further processing of lumber. It will also assist people who do not have a background in the abovementioned fields. It is based on the principle that most of the work and installations can be executed locally and by materials readily available. It also serves as a guide for equipment and components suppliers so that they can understand the full scope of the project and thereby exert better control over their designs and data.

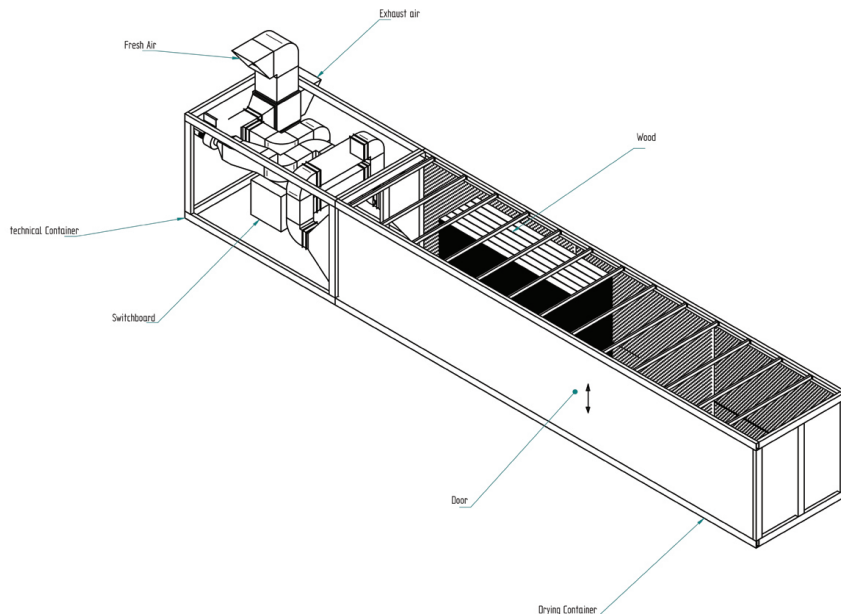


Large scale high temperature kiln

Overview

Practically all wood has to be dried in order for it to be utilised. Dried lumber shows improved characteristics in tensile strength and weight reduction, and is therefore highly suitable as a building material. It is also less likely to suffer from attacks by fungi and other organisms. Dry firewood creates a higher temperature flame and therefore more heat. This is because dissipated water had been previously removed during drying.

Whether the operation is big or small, drying can still be executed efficiently. The right balance between invested capital, labour costs and demand needs to be planned carefully.



Small scale vacuum lumber drier, TB Fladerer GmbH, Austria

Economics of drying

Lumber drying should be a money making operation. The best way to make money is to produce the best quality lumber possible. Time spent during drying, the usage of energy, labor costs, and other material expenses are all small compared to the costs generated by bad quality. An additional point to also consider is the cost of drying. Most importantly, lumber should not be dried to "remove moisture", but to make money.

It is a fact that kilns do not make money unless they are running. Therefore, the higher the kiln utilisation rate is, the more income it generates. Drastically simplified, this means:

$$\text{Earnings} = \text{Income} - \text{Expenses} - \text{Interest} - \text{Amortisation}$$

Where:

Income =	Revenue received from wood drying
Expenses =	Energy, labour and consumable costs
Interest =	Interest of the investment
Amortisation =	Portion of the total investment period under from the calculation is made

The total investment is divided to such amount of portions the investment is expected to run. This can be technical expectation (f.e.x. 10 years) or financial expectation (5 year loan). There is more to this, but basically the investment has to be calculated as a cost of doing business.

Calculational revenues:

25 cm x 100 cm, green, ZAR/m	3	march 2014
25 cm x 100 cm, dried, ZAR/m	7,2	march 2014
Dried to green ratio	2,4	
Drying revenue, ZAR/m	4,2	

Drying kiln chamber:

Width, m	2
Height, m	2
Length, m	6
Total, m ³	24

Stickering volume loss	9,69 m ³ (40 %)
Lumber batch for drying, m ³	14,31 m ³
25x100 board meters, rm	5723
Revenue per kiln batch, ZAR	24 036,60

Calculation expenses:

Work, two men loading, unloading, ZAR	250
Supervision, ZAR	500
Energy, for solar, ZAR	0
Materials consumed, ZAR	0
Total expenses per batch, ZAR	750

Calculation amortisation:

Solar kiln investment, ZAR	357 400
Amortized in 5 year payback, ZAR	71 480
Interest, 15 %, ZAR	53 610
Batch drying time	30 days
Annually possible batches	12

Ideally, these calculations would produce:

Earnings = Income — Expenses — Amortisation

12 x 24 036,60 — 12 x 750 — 53610 — 71480 ZAR

Earnings of 154349,2 ZAR. The above calculation is purely ideal, as there would virtually be no interceptions in the operations. If only half on the capacity could be utilised, the same parameter would give earnings of 14629,6 ZAR, so barely over the break even. Five loads per year would end up 8657 ZAR on loss. This also shows the importance of utilisation rate, how profitability of investments is lost if they are not used efficiently.

Components of plant

For starting a simplest wood drying operation, you would need some equipment. In the following table, we have collected some necessary equipment and grouped them by the needed minimum investment. As you saw from the previous chapter, when the investment grows, also the output and opportunity to earn grows.

ZAR	Non grid, air dry	Non grid, solar dryer unit	On grid, electric heated kiln unit	On grid, boiler heated kiln unit
Investment	32 172	307 096	380 690	445 072
Amortisation, annual	6 434	61 419	76 138	89 014
Expenses, annual	1 500	9 000	160 883	58 500
Revenue, annual	48 082	288 490	625 061	625 061
Income, annual	35 321	330 937	330 937	410 786
Bill of materials	Concrete blocks or tiles, as foundations and top weights for stacks	Sea container, 20 foot, used	Sea container, 20 foot	Sea container, 20 foot
	Stickers	Transport	Transport	Transport
	Corrugated sheets, to cover the stacks	PV solar panels, 280 W	Electric heater unit(s)	Boiler
	Capital for the work in progress	DC/AC inverter	Support structure, heater and fans	Warm water heat exchangers
		Variable speed controller	Variable speed controller	Variable speed controller
		Fans 3500 m3/h	Fans, 3500 m3/h	Fans, 3500 m3/h
		Exhaust valve, manual	Intake valve	Intake valve
		Intake valve, manual	Exhaust valve	Exhaust valve
		Temperature/Rh display	Temperature Rh display	Temperature sensor
		Wiring	Load sensors	Load sensors
		Air ducting	Regulating system	Regulating system
		Support brackets for PV panels	Wiring	Wiring
		Screws, bolts and nuts for the assembly	Air ducting	Air ducting
		Black paint		Heat distribution plumbing
		Stickers	Screws, bolts and nuts for the assembly	Screws, bolts and nuts for the assembly

Wood Drying Basics

Water inside wood moves from a higher to a lower zone of moisture content. In other words, "wood dries from the outside in." This means that the surface of the wood must be drier than the interior, if moisture is to be removed.

The drying process can be broken down into two phases:

1. The movement of water from the interior towards the surface of the wood.
2. The removal of water from the surface.

Water inside wood is held as free water and bound water. Free water is contained inside the cell cavities, and bound water is held within the cell walls. Free water within the cell cavities is held less tightly than bound water within the cell walls. Consequently, slightly more energy is required to remove bound water than free water. Free water does not affect as many wood properties as bound water. The removal of bound water affects many physical and mechanical properties, and therefore affects the quality and use of the wood.

The fibre saturation point (FSP) is defined as the moisture content at which "free water is completely gone, while the cell walls are saturated with bound water". In most types of woods, the fibre saturation point is roughly at 25 to 30% of moisture content.

Moisture content

Moisture content is the most important parameter in the wood drying process. It is defined as a percentage of the mass of the water in relation to the dry wood, assuming all water has been removed, i.e.:

$$\text{Wet weight} - \text{Dry weight} = \text{Water weight}$$

and

$$\left(\frac{\text{Water weight}}{\text{Dry weight}} \right) \times 100 = \text{Moisture Content (MC) \%}$$

It is therefore clear that the moisture content (MC) is based on dry substance. If there are equal amounts (weight) of water and dry wood in the sample, the MC will be 100 %. If all the water is removed from the sample, the MC of the sample will be 0 %. It also has to be kept in mind that a MC well in excess of 200% is possible in green cut woods and that this is quite common.

EMC

Cut wood adjusts its moisture content according to the surrounding atmosphere, temperature and humidity over time. This final moisture content is called the Equilibrium Moisture Content, or EMC. When wood is used outdoors, the EMC required is typically around 10% - 12%, whereas in an air conditioned indoor space, furniture might reach 6 - 7 % EMC. Therefore, depending on the usage of lumber, different MC's are required for the wood drying process as well.

There are three fundamental factors that influence the drying of lumber:

1. Heat – An increase in temperature will increase the evaporation rate and therefore reduce the drying time
2. Humidity – A decrease in Relative Humidity (RH) in air will decrease the drying time
3. Air circulation – An increase in airspeed will increase the evaporation rate and will reduce the drying time.

The fourth decisive factor is the control of the above three functions in such a way that required quality is achieved. Full quality control is therefore possible.

Quality issues in wood drying

Most softwoods can tolerate very harsh drying schedules, whereas hardwoods require more controlled treatments. Also, hardwoods are used extensively for in-house purposes, such as furniture and flooring. In such cases the EMC requirement can be 4-6 %. Softwoods are generally used for building purposes, where an EMC of 15 % is usually required.

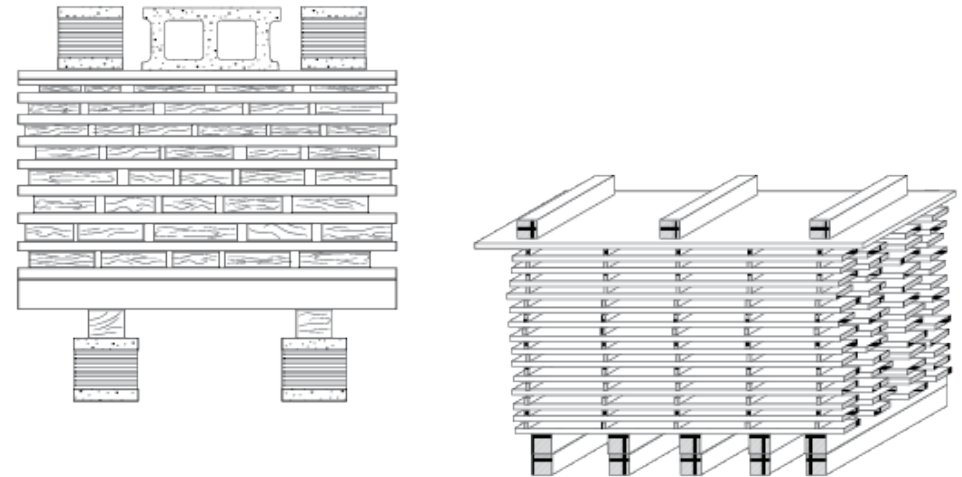
Stacking

Whether air dried or kiln dried, good stacking is fundamentally essential for good drying results. Stacking and stickering allows air to circulate evenly in the lumber pile. Stickers separate the adjacent layers of wood. A good "stacking" follows certain criteria:

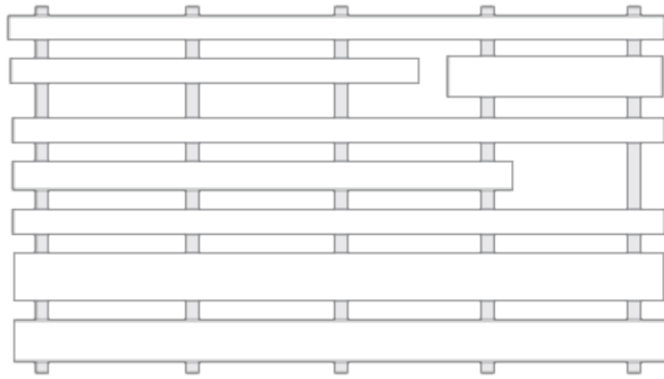
1. A stack should never be established on the ground. Evenly spaced and levelled concrete blocks, tiles, or kiln carts, etc. should be used to raise the first layer of wood. This is to avoid soil, dirt, dust, bugs, ground moisture or mold to cause the deterioration of the wood.
2. The end stickers should be as close as possible to the ends of the boards.
3. Stickers should be uniform in thickness and in line vertically in each layer of wood. If this is not done, the airflow might be disturbed and it might cause the lumber to be bent or warped.
4. Piles should be built on even lengths of wood. If this is not possible, a pile should be levelled at the end, leaving possible gaps leading to the inside of the pile.
5. If there are some wide boards or other pieces of lumber that need to be kept as straight as possible, they need to be piled at the bottom. The weight of the lumber above these boards will constrain them

from warping and bending and therefore produce the best result.

6. A pile should contain only pieces of wood with the same thickness. If this is not possible, each layer in the pile should be made up with wood pieces of the same thickness.
7. The pile of wood should be protected from direct sunlight or rain by covering it with suitable materials such as a corrugated metal roof or waterproof sheets. This will ensure that the top layer of wood is not affected by the elements. When air drying, there should be an additional set of tiles or weights to prevent the topmost layer of wood from warping and to keep the roof in place.



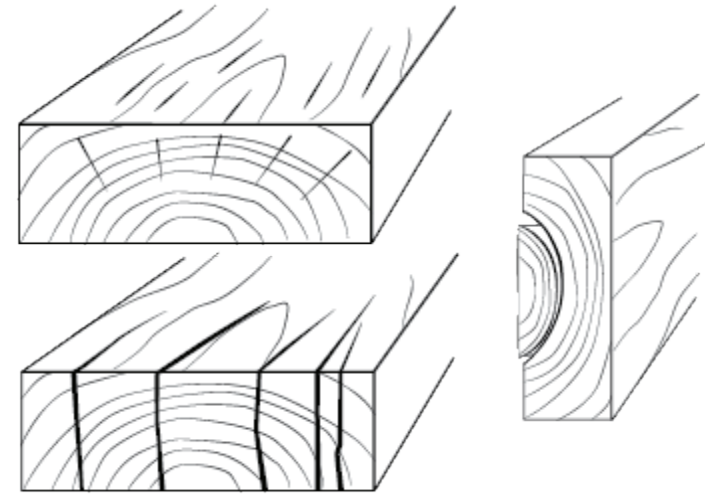
1. Stack is secured with cement blocks or other heavy items, placed on top of sticker lines
2. Plywood or roof protection against rain and sun caused uv radiation
3. Small inclination on the roof if there is a danger of rain(water)
4. Lower grade top cover
5. Boards in each layer are the same thickness
6. Best quality lumber at the middle and center of the pile
7. Thicker boards places at the bottom
8. Fundament is even



Top view of tier of boards, illustrating the system of alternating short lengths for piling. Unsupported ends of boards placed on the inside will dry with less defect than allowed to extend over the end pile. Having uniform pile also helps to gain unified drying results in the pile. With kiln drying it is also essential, as it reduces bypass air and baffling needs radically.

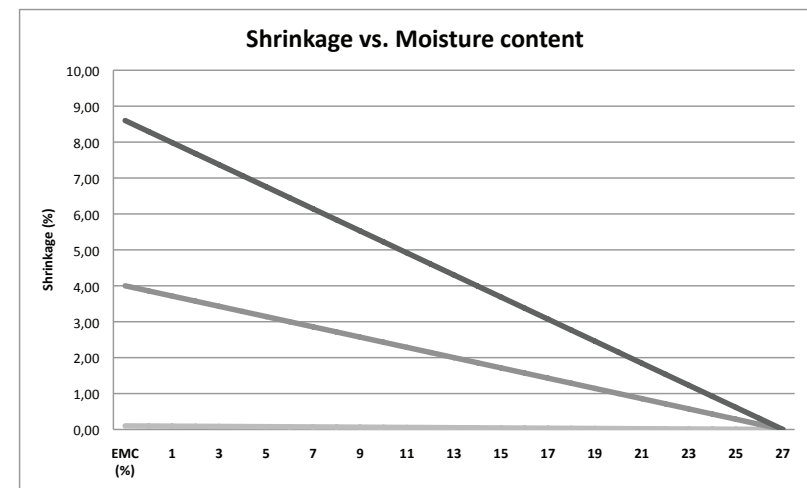
End checking or splitting

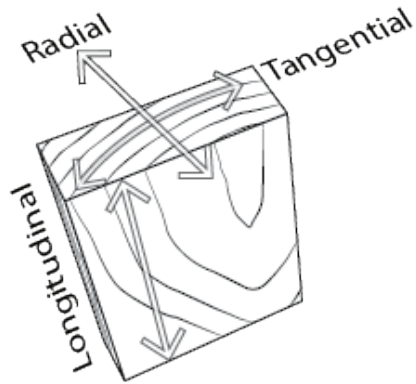
End checks have by far the greatest economic impact of all the quality issues when drying wood. End checks are cracks found in the end grains of pieces of lumber. This is caused when the lumber dries too quickly, causing the ends to dry out too soon. End checking often indicates that the RH is too low or that the air velocity is too high inside the dryer. These conditions result in surface checking and increase the risk of honeycombing as well. If these circumstances cannot be avoided or controlled, one way to reduce and eliminate the risk is to paint the ends of the wood planks with a moisture barrier. These end coatings are not usually required when lumber is placed in the kiln directly after being sawn. However, when lumber is air dried prior to kiln drying, end coating is often helpful in preventing end checks. Usually any paint will work on this.



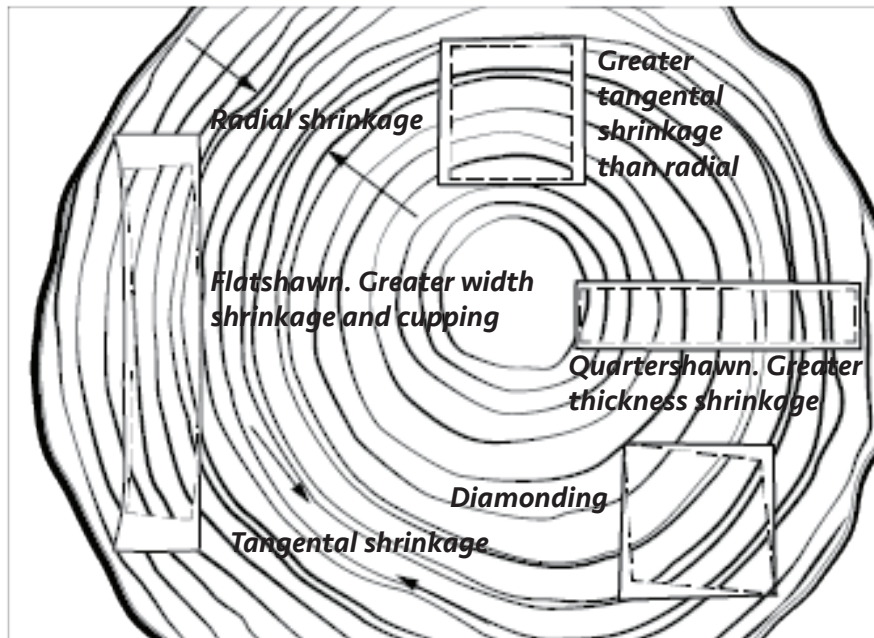
Deterioration

Wood shrinks when it dries. The most damage and deterioration is caused during the end phases of drying as the shrinkage increases when the wood dries. End checks are the result when lumber dries too fast. When the drying process is too quick it also causes uneven stress because the tangential shrinkage is twice as much as radial shrinkage. This can sometimes cause wood to "cup", "bow", "spring" or "twist".





When the drying process is too fast it can also cause case hardening. This is where the outer layer of the wood has dried, but the inside is still wet. This causes tension. When case hardened wood is sawn into pieces, the wood almost immediately transforms to bowed or crooked pieces of lumber.



Sample kiln drier construction with explanatory notes

Non-grid, solar only operation

There are several types of solar kilns. Normally they rely on solar heat collection in order to provide the heat energy required to evaporate the water in the lumber. Due to the large heat and air velocity requirements, most solar dryers lack adequate capacity without excessive investments.

When one has to remove a certain amount of water from a specific amount of wood, specific amount of total heat is needed to do it, and that heat requirement can't be changed. Drying times in a solar kiln are dependent upon the weather, and are therefore unpredictable. In hot climates they can degrade lumber due to excessive drying, if enough ventilation is not available. In colder climates they can be unreliable and slow. Solar kilns often use electric-powered fans to circulate air through the lumber and the cost of running these fans is high. Because of the long drying times, the fans have to run for long periods, and this makes solar drying quite expensive.

These characteristics of a non-grid, solar operation are as follow:

1. Drying green wood to 12 % MC takes 2-3 times longer than a conventional kiln (operating at temperatures below boiling point).
2. Drying is normally about twice as fast as air drying when drying down to 20-25 % MC, but thereafter is much slower and EMCs obtained vary between 6 and 12 %.
3. The quality achieved in solar kilns is high for the following reasons:
 - General rate of drying is slow when compared to conventional kilns.
 - Daily variations in temperature are larger than with air drying, but

variations in humidity are much lower. Humidity is relatively high during the critical drying period at moisture contents just below FSP.

- Humidity varies due to the day-night cycle. Air humidity can be around 90-100 % overnight, until MC of the charge is below 18-20 %, and the timber has a mild 'reconditioning' treatment every night.

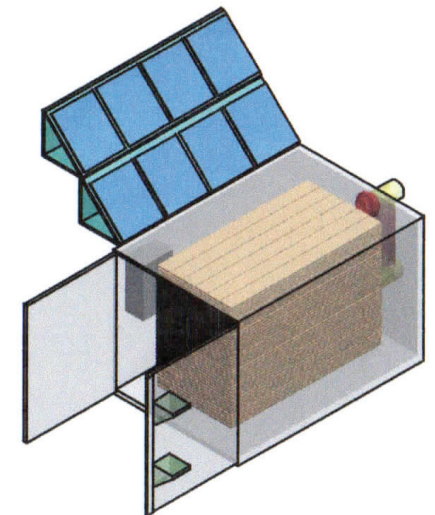
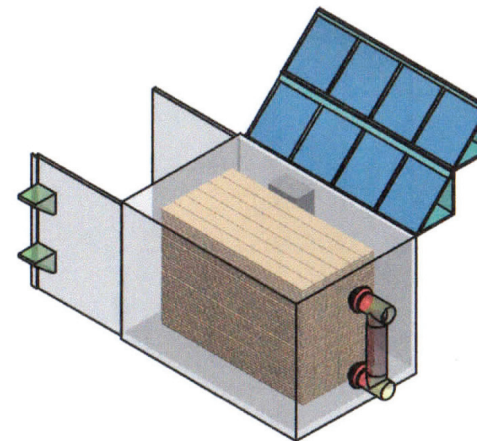
The kiln conditions are therefore very different from the conditions for air drying although this is not immediately apparent. The smaller solar kilns which contain small volumes of timber in relation to their total volume and surface area tend to produce more severe drying conditions in the middle of the day than do the larger kilns. The results are case hardening and other defects in that are caused in the smaller kilns. The larger kilns do not appear to suffer from these defects if correctly vented.

Design principles of an on-grid, solar only operation

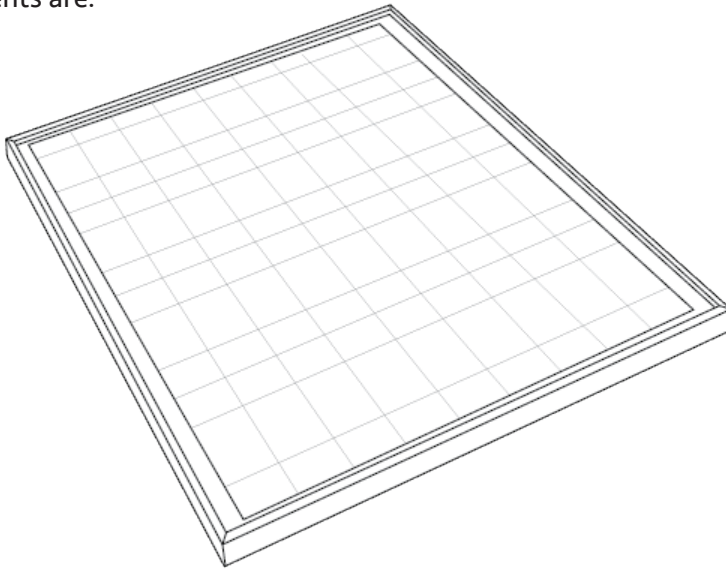
The non-grid, solar drying kiln is based on the the following design rules:

1. The setup is based on utilising a used 20 foot sea container. Other similar structures can be used instead of a sea container.
2. The container should be located at a sunny location and free from any obstacles that might cause possible shadows. The sides and roof of the container must be painted matt black and directed towards the sun.
3. The photovoltaic PV solar cells (12 units), are standard 1000 x 2000 mm 72 cell panels, each producing a peak power of 280 W. This roughly equates to 3,6 kW total peak power. At night there is no electricity because there is no battery array to charge during the day.
4. The PV solar panel support structure must be mounted at the edge of the roof of the container. The panel should be tilted and adjusted per perpendicular to the sun in order to receive the maximum amount of sunlight.
5. The front door must have two fresh air vents.

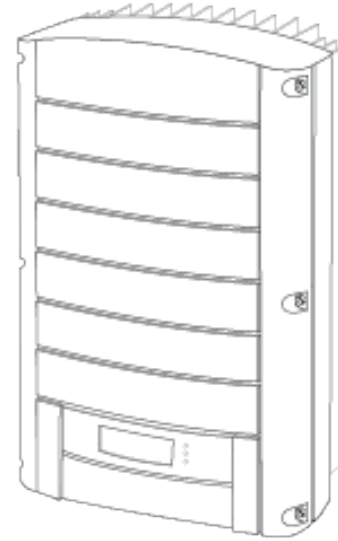
6. The two fans (each 1,8 kW, 600 mm diameter), will produce 1,9 m/s of maximum air circulation to the drying chamber during the peak hour.
7. Each fan has an exhaust valve and they are connected to each other with an air duct for internal circulation.
8. The cabinet contains a DC/AC inverter drive unit and a PLC (Program mable Logic Controller) which is necessary to control the fans and the vents.
9. The surface of the container is utilized as a solar energy collector and is painted in matt black for maximum heat absorption capability.



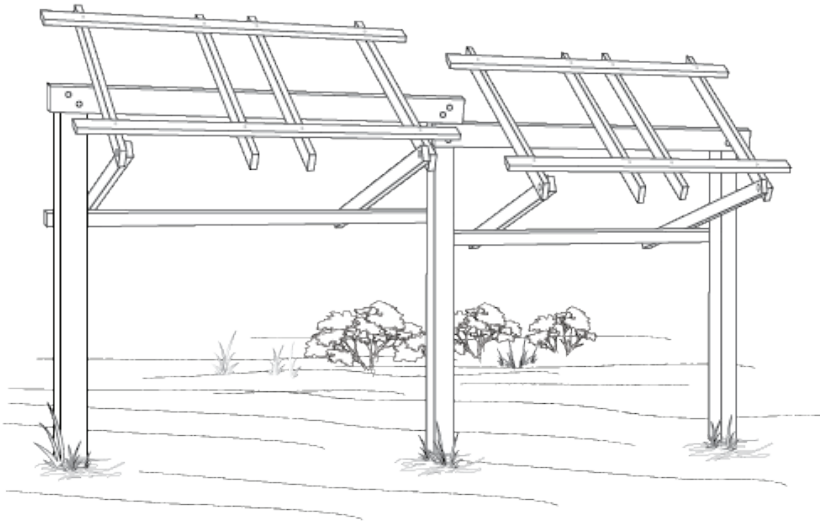
The components are:



12 Units of standard 280W solar panels



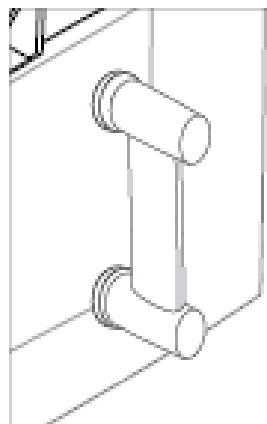
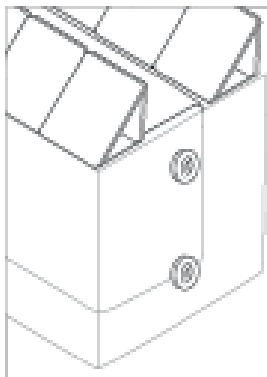
In order to utilise the PV generated electricity, it has to be inverted from DC to AC voltage. This is done by a DC/AC inverter.



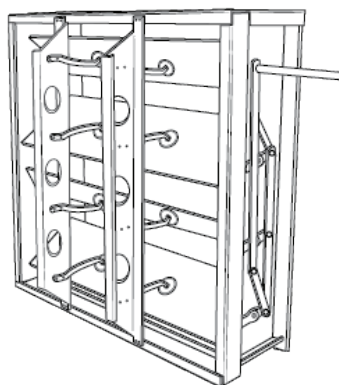
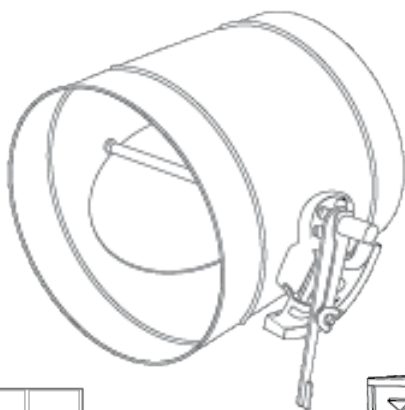
Panel support system with reasonable adjustment. If lumber is available, why not use it? Check your optimum panel angles from: <http://solarelectricityhandbook.com/solar-angle-calculator.html>



2 Axial blowers, approximately 1,8 kW each.



The blowers are installed vertically to the non door end of the container. They should both be connected with air 2 manual dampers shown below.



2 Adjustable air intake dampers. The intake dampers should be located at the container door panel.

Treatment schedules for solar dryer

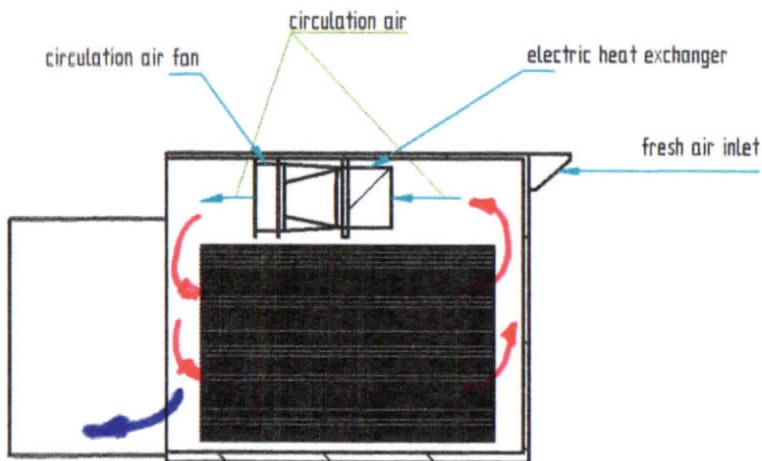
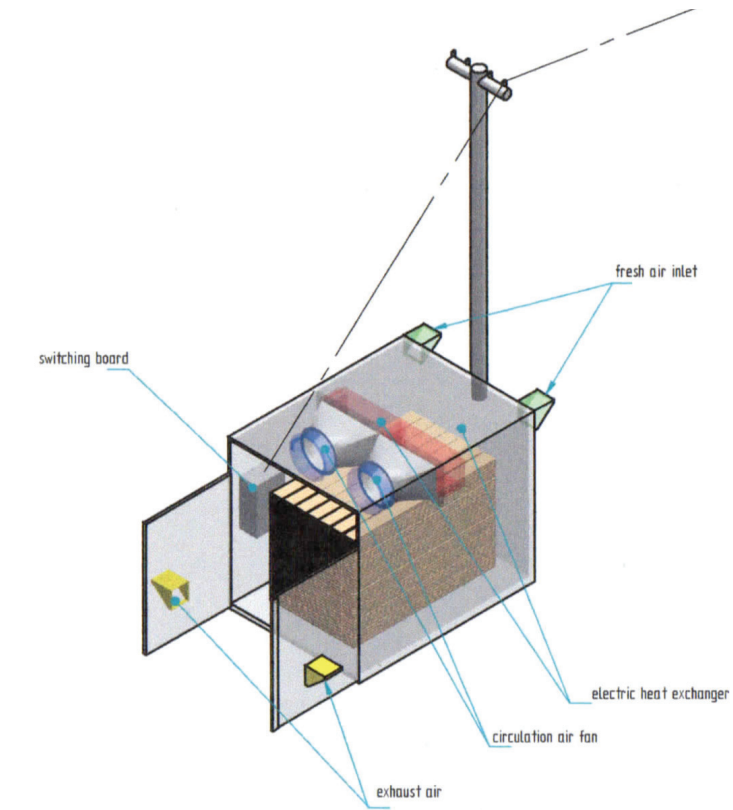
There is no external heat source for a Solar Dryer, except for the sun's heat energy that is emitted through the black painted container wall and roof. The treatment principles differs from a heated dryer kiln.

On-grid operation

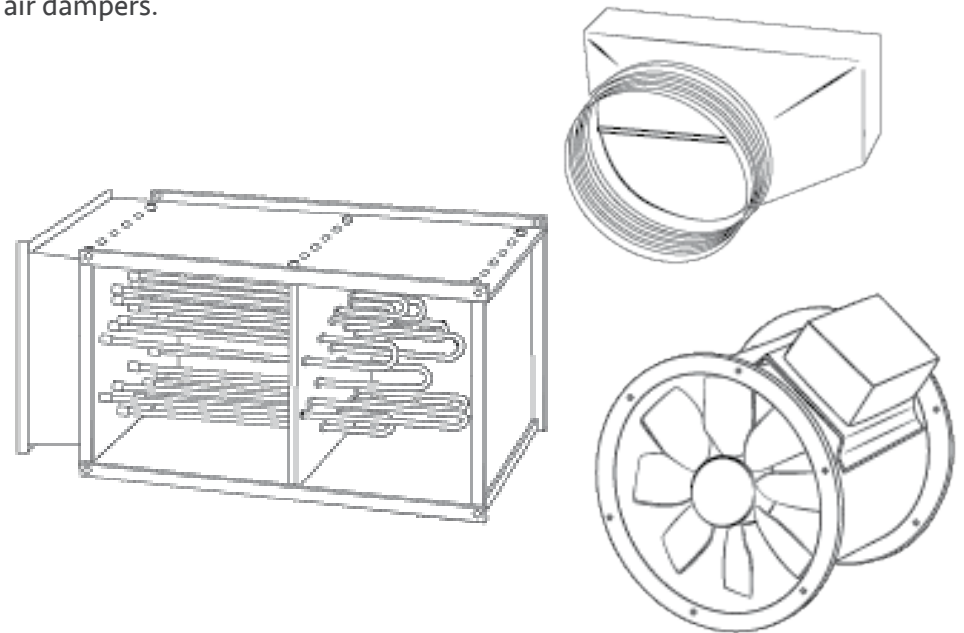
In the on-grid, electrically heated kiln, the external heat is produced by electricity. This might or might not be economically viable, depending on the availability and price of electricity. On the other hand, on-grid electricity is a more reliable power source for the circulating fans and heat generating elements. This provides the operation with much more options than when relying solely on PV panels. The container and components required are usually generally available.

The proposed structure is a standard refrigerated 20 foot shipping container (commonly known as a "reefer").

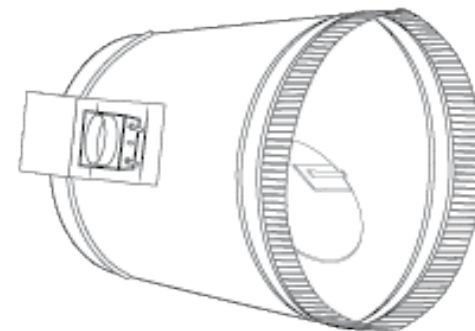
Do not use a standard non-refrigerated shipping container because it is not built with materials that will survive as a kiln. There are elevated temperatures in conjunction with high relative humidity (RH) % factors and therefore the standard container is not suitable. "Reefers" work well and last a relatively long time. If there are no second hand reefer containers available, a standard container can be used but it has to be insulated. Glue foam board, styrofoam or EPS board to the inside ceiling, sides and ends of the container. If possible, use an adhesive to glue a radiant foil barrier over these insulating boards. Foil barriers are available under several brand names like Prodex, Reflectix, Tek foil, Eco foil and Tempshield. These foils provide excellent radiance and are highly effective as a moisture barrier. If such materials are not available, any insulation is better than no insulation. Clean and paint all exposed metal surfaces inside the container, as moisture will condense and cause the metal to rust.



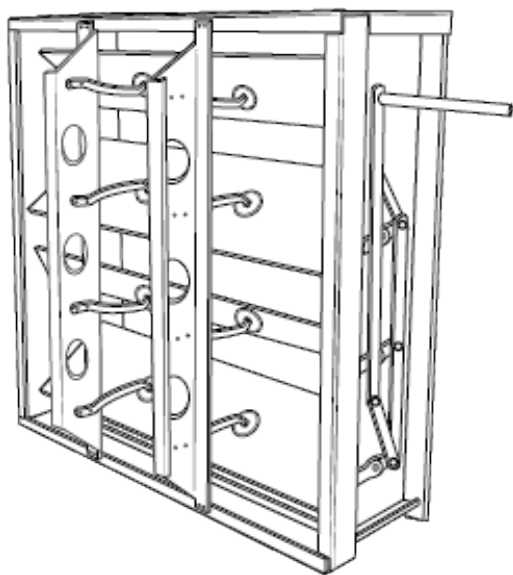
The main purpose of the heat exchanger and fans is to generate heated air and circulate it inside the kiln in order to dry the lumber. The RH level and temperature of this circulating air can be controlled with intake and exhaust air dampers.



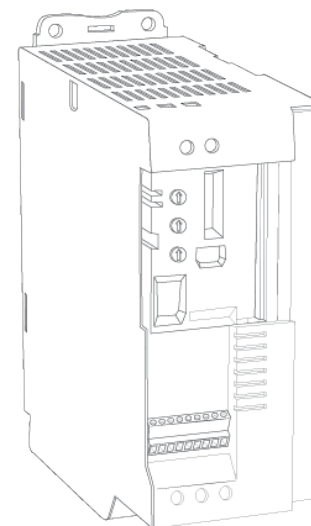
The main component in this system is the heat exchanger and fan modules, as can be seen in the image above. They are fitted together with duct adapter. The fans must be hanged from rubber mounts. The intake and exhaust dampers are basically the same as in the solar alternative. Because there is a PLC in this unit, the dampers are controlled by motors.



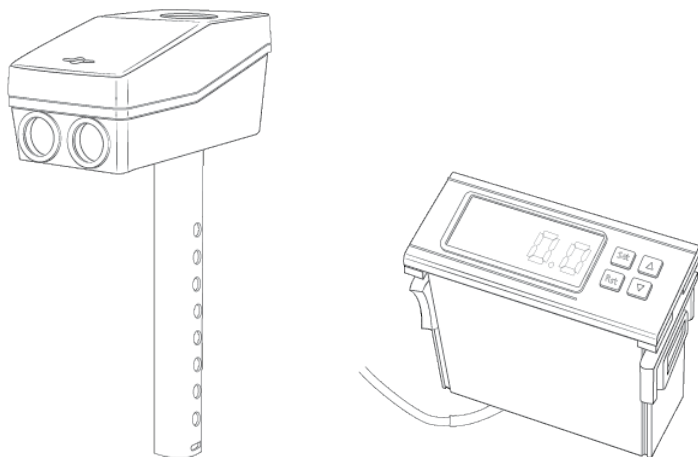
URD exhaust air damper



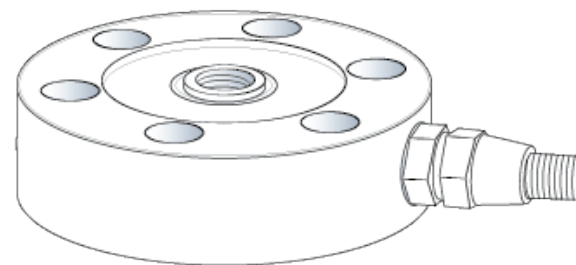
Motor controlled intake damper



The blowers are run by variable speed drives (VSD's). These units can ramp up, slow down or reverse the blowers and are controlled by the Programmable Logic Controller (PLC).



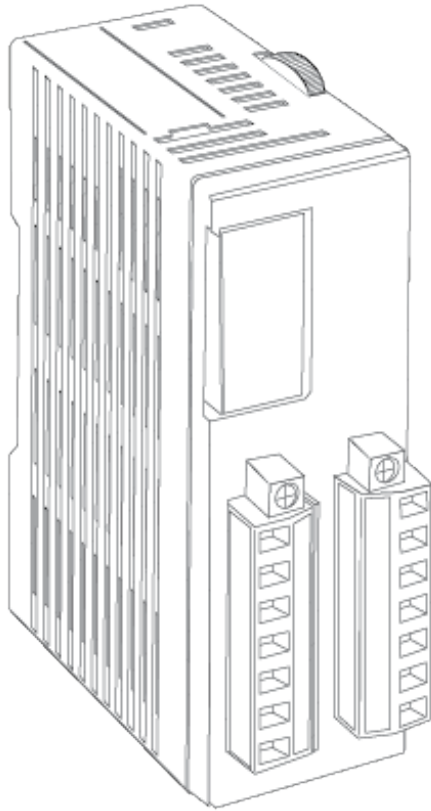
A temperature-hygrometer sensor with controller gives an approximation of the internal conditions (RH and Temperature) inside the kiln during the drying process.



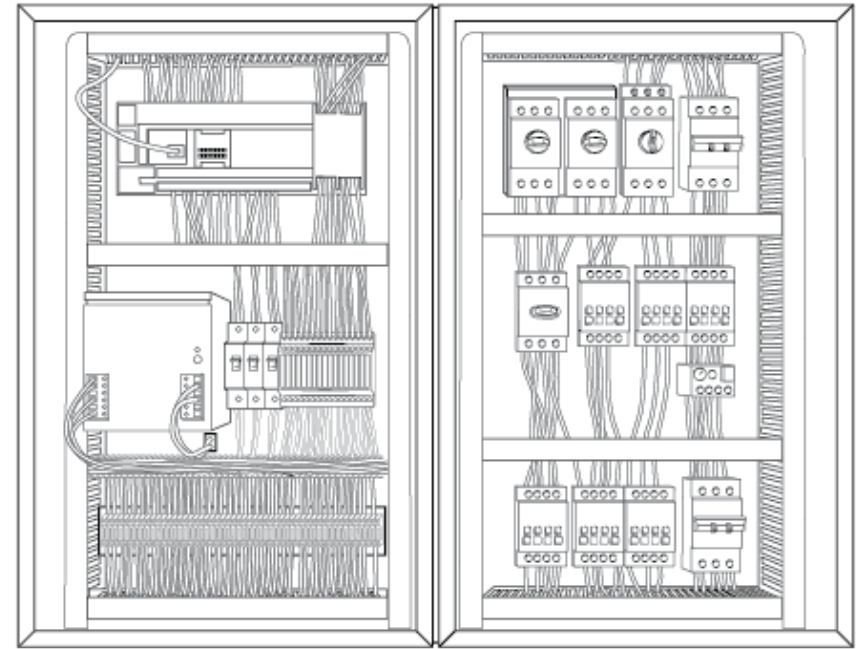
Load cell

Load cells can be substituted for RH sensors as part of the controls equipment used during the drying process. After all, drying is basically the removal of water from the lumber. When we know what the weight of lumber at the start of the drying process is, and what the desired end MC lumber weight should be, we can easily control the drying process by measuring the weight reduction inside the drying chamber. This can be done with two compression load cells that are installed at diagonal corners of the container. They should carry the

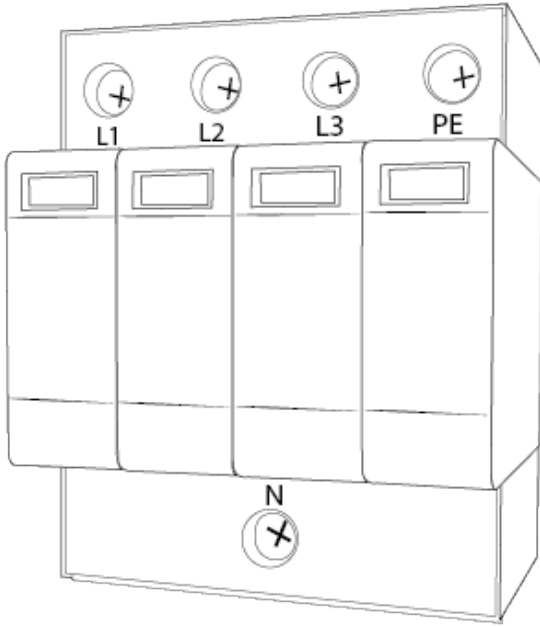
weight of the container, as they are measuring the weight of the evaporated water from the inside to the outside of the container. The load cells should carry approximately 2000kg load for a 20 feet container.



A Programmable Logic Controller (PLC)



A Programmable Logic Controller (PLC) is the “brains” of the entire system. It controls all the equipment and executes the program that is installed on it. A PLC is normally resides inside a metal electrical cabinet, with lots of other essential components. Unless you are familiar with PLC programming, talk to a certified electrician or automation specialist to install a complete cabinet with a PLC, I/O cards, contactors, relays, fuses, power supply and other electrical switch gear into an electric cabinet.



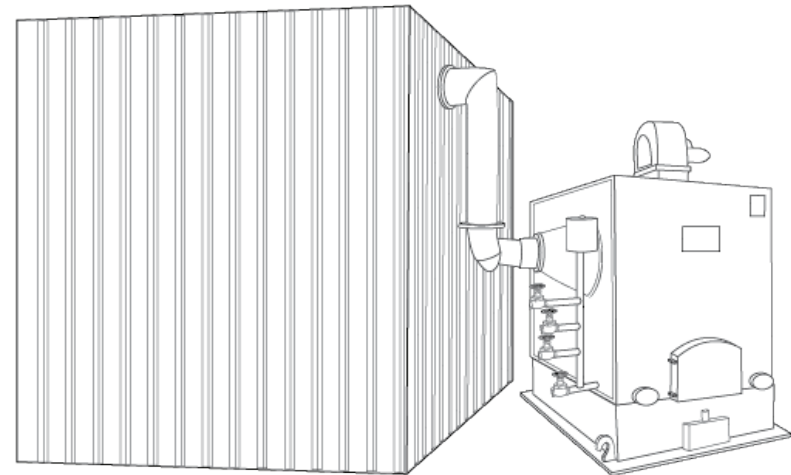
The AC electrical supply might be subject to possible power outages or surges (such as when a tree strikes a power line). Be sure to install a surge protector in your electrical control cabinet. These surges can originate from the grid and therefore the kiln controllers might be susceptible to sudden and intense voltage fluctuations.

On-grid with chip wood burner

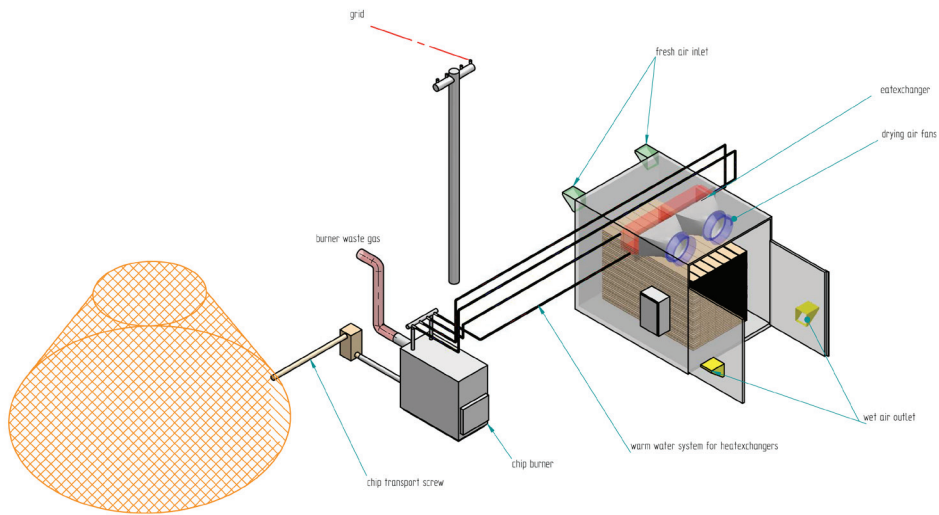
The idea of a wood chip burner is to use “free” energy from sawdust to dry the lumber, pertaining to the fact that sawdust is generally available from the sawing operations. There are certain issues regarding the use of sawdust as a fuel. The energy content of dry sawdust with a MC of 13% is around 13 MJ/kg, but it is less than 10 MJ/kg in the case of sawdust with a MC of 50 %. Sawdust also contains a lot of air, which makes it quite bulky. Sawdust also sticks quite easily, and often creates difficulties when sawdust is fed automatically into the burner.

There are two main types of boiler drier kilns:

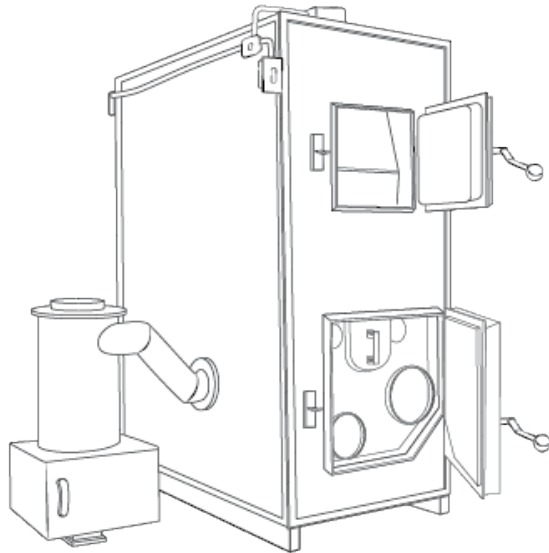
1. Direct heat boilers, where the kiln is heated with boiler exhaust gasses that are ducted to the drying chamber.
2. Boilers with water circulation. A furnace is needed to transfer the heat energy into the air or water. If water is used, there needs to be a heat exchanger, piping and a circulation pump with valves.



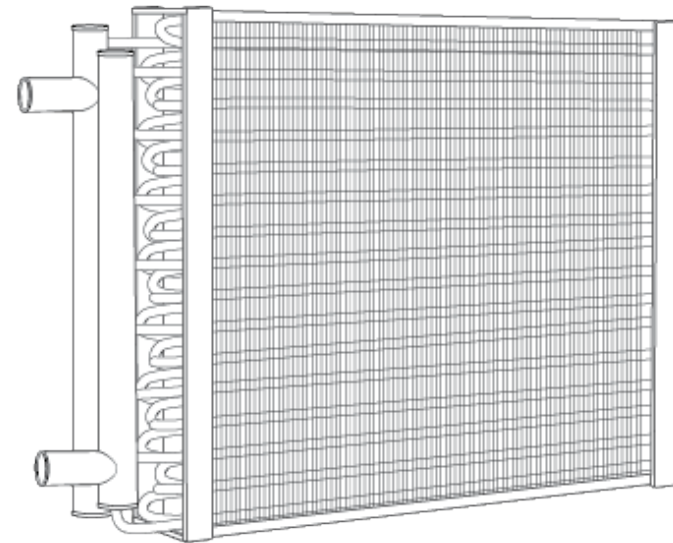
Wood dryer with direct heat boiler.



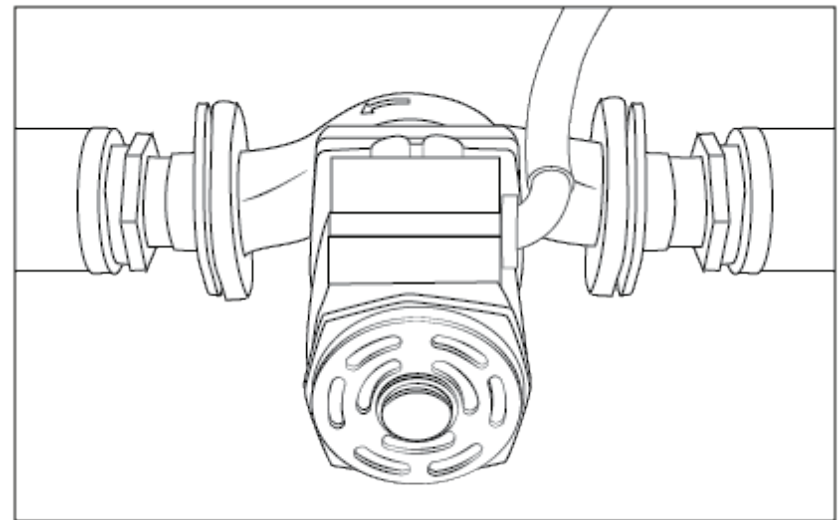
Principle of water boiler heated dryer kiln

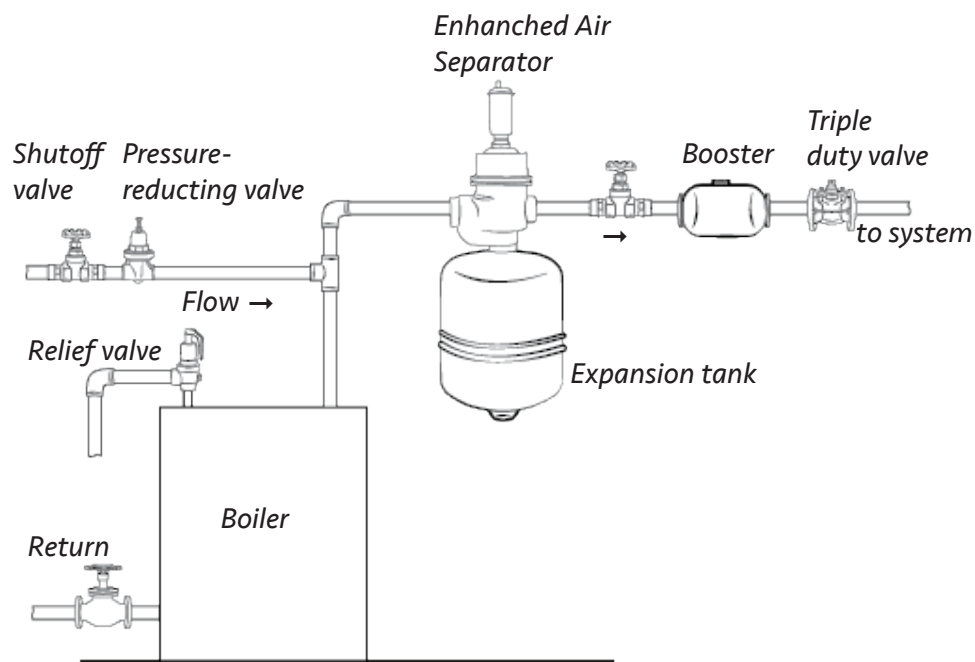


In principle, any boiler can be used to burn sawdust, if it is fed manually. If the operations require automatic sawdust feeding, it raises the investment significantly.

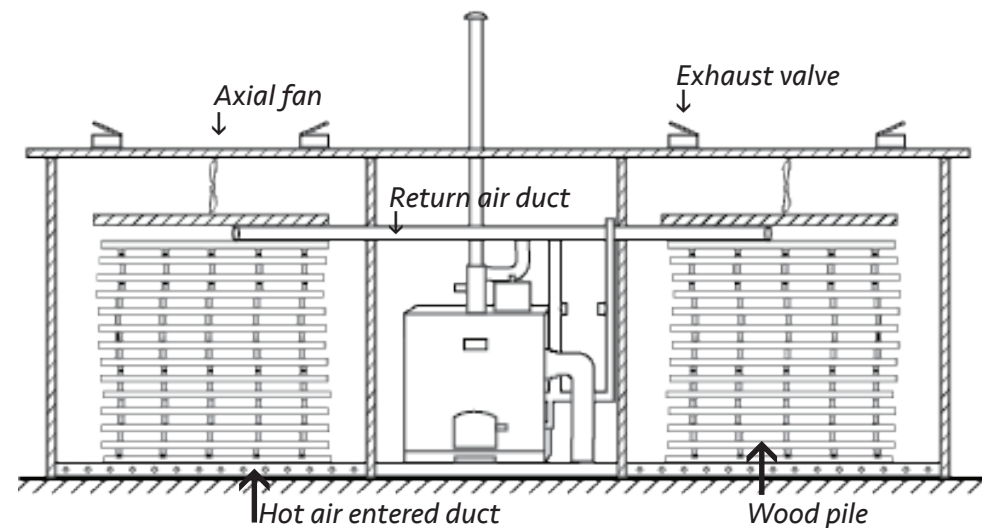


A water-air heat exchanger is located next to the circulating fan inside the drying chamber. It transfers the heat from the circulating water inside the heat exchanger to the air inside the kiln. The installation requires incoming and outgoing piping which is suitable for hot water. The piping should be well insulated.





Compulsory safety equipment like a system relief valve and expansion tank also needs to be installed. Because the boiler system is a low pressure fluid system, a certified plumber is required to do the installation. An improper installation may lead to an explosion, material damage and even human casualties.



One boiler can supply two or more kilns, either simultaneously or each one individually.

Treatment schedules

Temperature and Relative Humidity (RH) are the variables that dictate the drying process. We will assume that the air velocity is kept constant. The different wood species and the end uses of wood both require different processes, stacking variations and air flows, etc. The drying schedule formulation therefore becomes a tremendously complex task. Although there are many reference schedules, finding the right one for your lumber, with your available equipment, is always a case of "trial and error". For the starting point, there are two basic schedules represented below, one for hardwood (furniture purpose) and the other for softwood (building use):

Hardwood time based schedule. Wood thickness 50 mm. Start MC 60 % and end MC 8 %

Chamber temperature, C	Relative humidity, RH %	EMC %	Guided duration, days
60	90.3	17	1
75	59.7	8	2
80	47.7	6	2
80	36.6	5	3
80	29.1	4	3

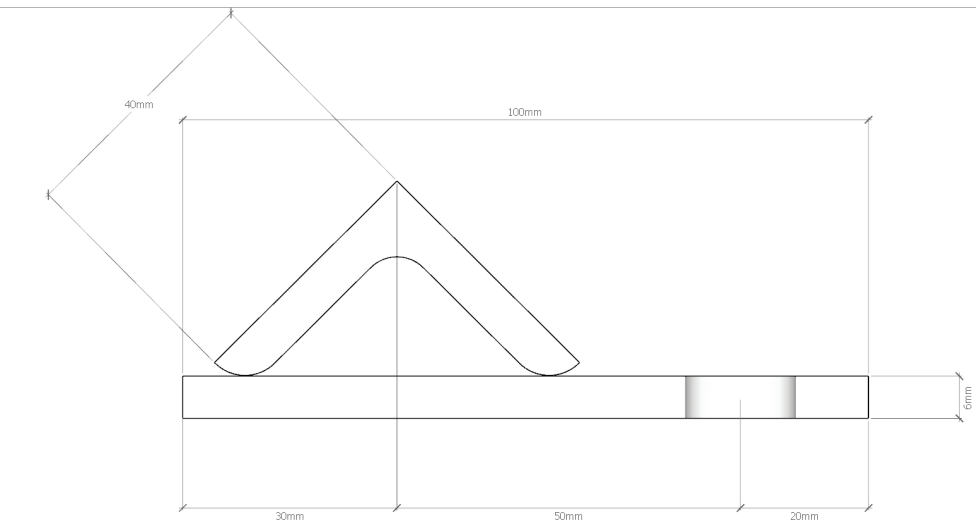
Softwood (Pine) based schedule. Wood thickness 50 mm. Start MC 80-100 % and end MC 12 %

Chamber temperature, C	Relative humidity, RH %	EMC %	Guided duration, days
50	74	13	1
55	70	11	1
70	64	9	1
70	60	8	1
75	50	7	1
75	30	4	1

These principles can be written into PLC program code, together with necessary controlling features, switches in the cabinet. There are lots of ways to program a PLC. PLCs use slightly different dialects on the programming, so it is better to consult your PLC provider for this.

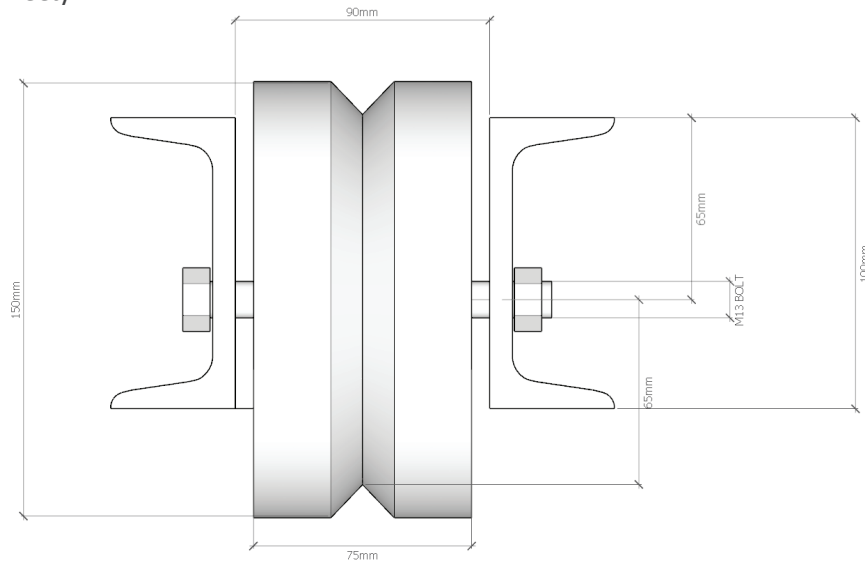
Track system for easy loading and unloading

A track system has several advantages over manual loading and unloading by hand. It speeds up the operation, encourages good stacking and saves the kiln from potential damages caused by manual loading and unloading. The tracks also allow the use of a forklift for changing the loads. Firstly, build a track system inside the kiln. Secondly, extend the tracks outside the kiln at least 2-3 times the length of the kiln (including the length of the door when it is opened). A suitable rail gauge can be determined by dividing the effective kiln chamber width by 3. An opening will have to be cut in the doors in order to close them. Thereafter, manufacture a seal based on the profile of the cut. This seal is to be used when the kiln is in operation.

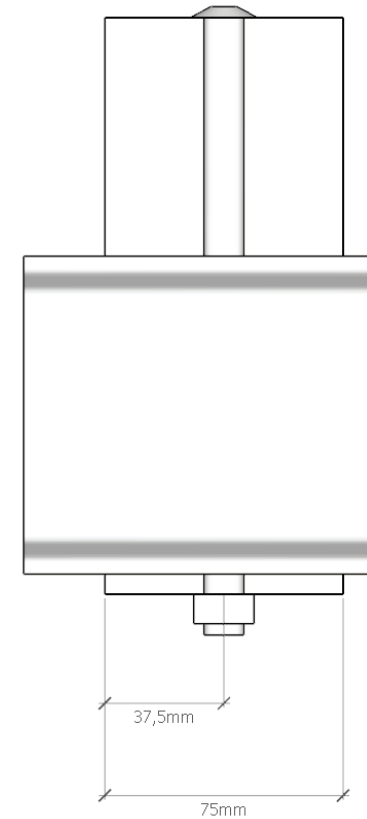
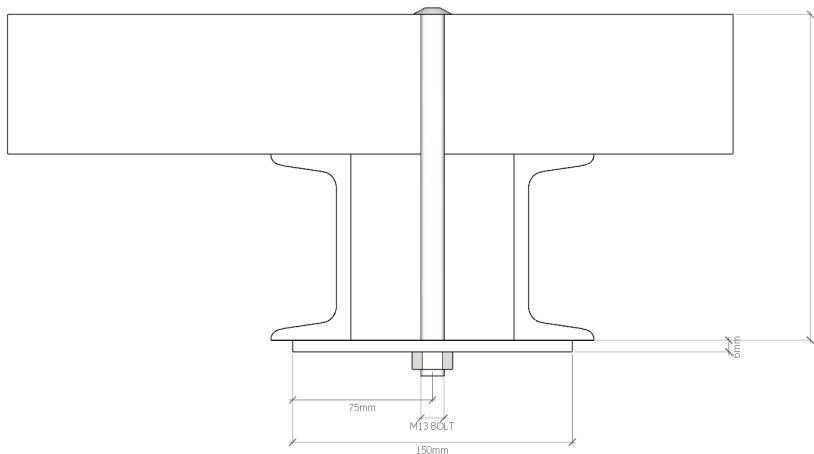


L-profile based rail

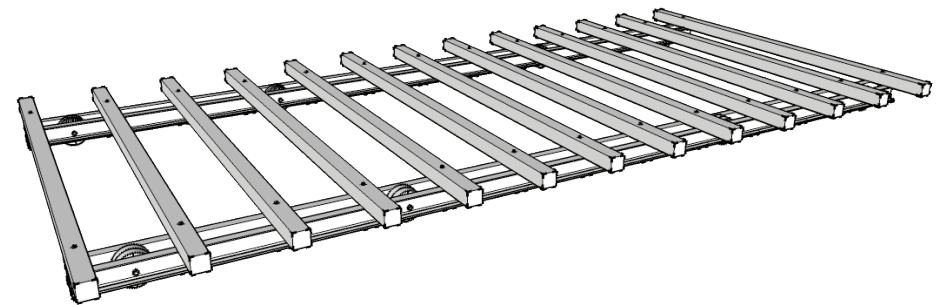
A L-profile steel bar with a 20-40 mm profile can be used as a leading rail on the ground. By welding small plates to the profile, it can be connected to supporting beams. The other rail should be made of flat steel to allow wheel to roll freely.



The guiding wheel on the side of the cart should have a groove that fits to a L-profile track. Use at least one wheel for every meter along the length of the cart. Bolts with a minimum diameter of 12 mm should be used (as wheel axles) as the load on the cart can be as high as 3 tons. Use U channels with L profiles on both sides of the wheel to form the one side section of the cart.

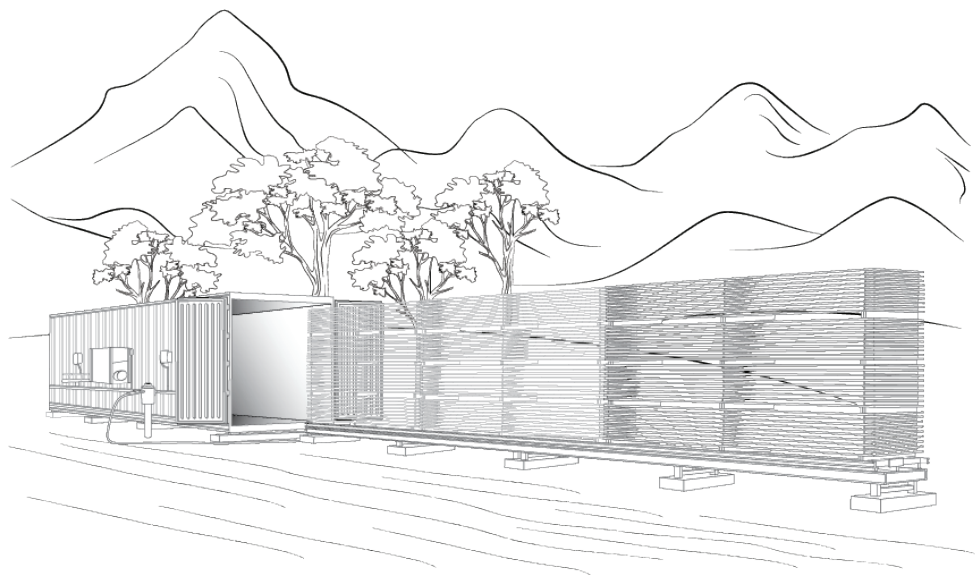


The sides of the cart can now be joined together together with wooden beams.
Modified from Source: http://www.nyle.com/downloads/L200Manual_Web.pdf



You should have something like this!

Putting your Plant on Paper



There are both economical and technical questions that need to be asked before starting a lumber drying operation. To start off, one should look around and see what kinds of resources are easily available for the project. At this stage, the required resources that need to be purchased should be put in a list. By estimating the prices of the items on the list it will be easy to determine the economic feasibility of the project, and how to make ends meet. By the time all the required items have been listed, one might already have an idea of what the project should look like. Most of the economic questions have already been discussed, and in the next phase the focus will be on the project execution.

The project feasibility outline, on paper, should include (but not limited to) the following:

Technical feasibility study

- The main design in words and with illustrative sketches.
- Resources, bill of materials.
- Points of purchase, including transport costs.
- Outside workforce, estimations on duration and cost
- Estimation on your own work and input

A brief business plan

- Who is your market, and what are the price levels you can obtain?
- Who are your raw material suppliers, including their stability and prices?
- Your estimated investment costs
- Your running capital required
- Cost of operations and materials, capital costs
- Cash flow calculation

Unless you are familiar with the abovementioned issues, you should seek professional advice (at least to check your numbers). Any local accountant is capable of doing this. You should leave room for uncertainties as projects do not always execute as smoothly as they have been planned to.

Project preparation

Apart from the complex technical and economical requirements as outlined in the field guide, legal and administrative aspects also needs to be considered.

After collecting the basic economic and technical data and drafting a project outline, you should contact the authorities for the following aspects in order to establish the overall feasibility of the project:

- ☐ Power sourcing, conditions and tariffs.
- ☐ Land use, ownership, transmission rights.

- Environmental restrictions.
- Ecological impact, influence on farming, fishing, forestry, landscape, protected areas, nearby communities, etc.
- Permission for planning and construction.
- Financing facilities, subsidies, government support and other factors that might influence the feasibility of the project.

Project implementation schedule

There are numerous stages in the project that interlace with each other:

1. Planning of project
2. Clearance with authorities
3. Financing arrangements
4. Stakeholder meetings
5. Project implementation
6. Contracts with suppliers and contractors
7. Supervision and execution of work
8. Deliveries and construction
9. Commissioning, training, handing over
10. Start of operations, learning the drying operations
11. Modifications to equipment and processes

Environmental protection

The unsustainable use of forest resources inevitably causes deforestation. Degradation of the natural environment (due to deforestation), growing erosion and the expansion of agricultural land use can lead to a reduction of water flow during the dry seasons and may cause many other harmful environmental issues.

In order for a mill to be sustainable, the forest resources in the catchment area have to be protected by all users of those resources. This includes the mill management, surrounding communities and individuals. As a basic principle, the national regulations for the protection of the environment should be adhered to. In cases where re-forestation programs are not part of the national interest, it should definitely be in your and your community's long term interest.

Initially, an environmental impact study has to be done in order to assess the impact on the environment and the required measures that have to be taken in order to protect it. After this, all parties involved (Forestry, Agriculture, Irrigation, Water supply, Water Management, Watermills etc.) need to come together to draw up an environmental protection plan.

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Useful information on Internet

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<https://youtu.be/PufOzqKnOmK?list=PL-H1x1eiZPydvHtltF7IpG0sJYvZqjhe&t=77>
<https://www.youtube.com/watch?v=Wpg0roBCHQI&list=PL-H1x1eiZPydvHtltF7IpG0sJYvZqjhe&index=27>

Electric dryer kin

<https://youtu.be/2dlRUCKciw0?list=PL-H1x1eiZPydvHtltF7IpG0sJYvZqjhe&t=21>

Chip boiler kiln

<https://www.youtube.com/watch?v=tQBpHQUjFNA>
<https://www.youtube.com/watch?v=L9mED3cgzql>
<https://www.youtube.com/watch?v=LDDW7frhlek>

Books

HARDWOODS (primarily)

Drying Oak Lumber by E. M. Wengert. Available from University of Wisconsin-Madison, Department of Forest Ecology and Management, 1630 Linden Drive, Madison, WI 53706.

Kiln Operator's Manual for Eastern Canada by M.Y. Cech and F. Pfaff. Available from Forintek Canada Corp., 800 Montreal Rd., Ottawa, CANADA K1G 3Z5.

Opportunities for Dehumidification Drying of Hardwood Lumber by E. M. Wengert & others. Available from Virginia Forest Products Association, P.O. Box 160, Sandston, VA 23150.

Drying Hardwood Lumber by Joe Denig and others. Available from the Wood Education and Resource Center, 301 Hardwood Lane, Princeton, WV 24740-7513.

Quality Drying Of Hardwood Lumber-Guidebook-Checklist by R. S. Boone. Available from the U.S. Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398.

Effective Predryer Operations by K. Eckert and R. Little. Available from the Forest Products Society, 2801 Marshall Ct., Madison, WI 53705.

SOFTWOODS (primarily)

Drying Southern Pine Lumber by E. M. Wengert and J. R. Beckwith, III Available from Southeastern Lumber Manufactures Association, P.O. Box 1788, Forest Park, GA 30051.

High Temperature Drying by Larry Culpepper. Available from Miller Freeman Books, 600 Harrison Street, San Francisco, CA 94107.

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Drying Pacific Northwest Species for Quality Markets. Conference Proceedings. Available from the Forest Products Society, 2801 Marshall Ct., Madison, WI 53705

Quality Drying of Softwood Lumber-Guidebook-Checklist by M. Milota and others. Available from U.S. Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398

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Storage of Lumber by R. C. Rietz, U.S. Dept of Agriculture Handbook No. 351. (Out-of-print: See library for copy.). The Conversion and Seasoning of Wood by W. H. Brown. Available from Linden Publishing, 3645 N. Blackstone, Fresno, CA 93728.

Air Drying of Lumber by the U.S. Forest Products Laboratory. Available from the Wood Education and Resource Center, 301 Hardwood Lane, Princeton, WV 24740-7513.